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# Geophysical Pilot Test Plan

Nevada Environmental Response Trust Site

NERT Remedial Investigation – Downgradient Study Area
Henderson, Nevada

Final

# Geophysical Pilot Test Plan, Revision 0

**Nevada Environmental Response Trust Site**
**NERT Remedial Investigation – Downgradient Study Area**
**Henderson, Nevada**

**Responsible Certified Environmental Manager (CEM) for this project**

I hereby certify that I am responsible for the services described in this document and for the preparation of this document. The services described in this document have been provided in a manner consistent with the current standards of the profession and, to the best of my knowledge, comply with all applicable federal, state and local statutes, regulations and ordinances.

| | |
|---|---|
| Sally Bilodeau (signature) | July 11, 2016 |
| **Sally W. Bilodeau, CEM** | Date |
| **Downgradient Study Area Project Manager** | |

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# List of Acronyms/Abbreviations

| | |
|---|---|
| µg/L | micrograms per liter |
| bgs | below ground surface |
| BMI | Basic Management, Inc. |
| Downgradient Study Area | NERT Remedial Investigation – Downgradient Study Area |
| DQO | data quality objective |
| ENVIRON | ENVIRON International Corporation |
| EPA | United States Environmental Protection Agency |
| ERI | Electrical (Direct Current) Resistivity Investigation |
| GPT | geophysical pilot test |
| GPTP | Geophysical Pilot Test Plan |
| HASP | Health and Safety Plan |
| ID | identification number |
| IDW | investigation-derived waste |
| LVW | Las Vegas Wash |
| MASW | Multichannel Analysis of Surface Waves |
| NDEP | Nevada Division of Environmental Protection |
| NERT | Nevada Environmental Response Trust |
| NERT On-Site Study Area | on-site portion of the NERT Remedial Investigation Study Area |
| QA | quality assurance |
| QAPP | Quality Assurance Project Plan |
| QC | quality control |
| ReMi | Refraction Microtremor |
| RI | Remedial Investigation |
| RM | river mile |
| SOP | Standard Operating Procedure |
| SR | Seismic Refraction |
| TDEM | Time Domain Electromagnetics |
| UMCf | Upper Muddy Creek formation |

# 1.0 Introduction

This Geophysical Pilot Test Plan (GPTP) describes the survey locations, procedures and methods for the geophysical pilot test (GPT) to be conducted within the Nevada Environmental Response Trust (NERT) Remedial Investigation (RI), Downgradient Study Area (herein referred to as the Downgradient Study Area) in Henderson, Nevada (**Figure 1**). This GPTP was developed at the direction of the Nevada Division of Environmental Protection (NDEP) to evaluate three geophysical systems for potential full-scale implementation: electrical resistivity, seismic refraction and electromagnetics. A GPT will be conducted for each of the proposed technologies at two locations within the Downgradient Study Area.

The Downgradient Study Area is located outside of the NERT RI On-site and Off-site Study Areas. The objective of the investigations in the Downgradient Study Area is to identify subsurface pathways downgradient and cross gradient of the NERT RI Study Area through which perchlorate-impacted groundwater is entering Las Vegas Wash (LVW). Paleochannels have been hypothesized as the primary avenue of transport of perchlorate in groundwater to the LVW; however, other preferential pathways may exist. Recent data indicate that much of the perchlorate mass in the paleochannels has been flushed. It is possible that paleochannels still account for significant mass flux to the wash due to their high flow volume even though the perchlorate concentrations have diminished. The location of paleochannels, as well as other potential preferential flow pathways, is important to the understanding of perchlorate mass flux to the wash outside the NERT RI Study Area. While limited geophysical surveys have been conducted in the area, uncertainties remain as to the locations of these channels in the vicinity of the LVW. The proposed surface GPT will be used to evaluate three geophysical systems, including the feasibility of employing the systems under constrained access conditions, cost effectiveness, and their effectiveness at identifying the top of the Upper Muddy Creek formation (UMCf) and paleochannel geometry. The GPT results will be used to select the optimal approach for a full-scale geophysical investigation along the reaches of the LVW within the Downgradient Study Area.

The activities in this GPTP will be conducted in conformance with the site-specific Health and Safety Plan (HASP) developed by AECOM. The HASP will be updated, as needed, with the geophysical subcontractor's safety protocols and reviewed for conformance with AECOM safety protocols prior to mobilization into the field.

## 1.1 Geophysical Pilot Test Plan Organization

This document includes the following sections:

- Section 1.0 provides an introduction, including the overall objectives and scope of the GPT.
- Section 2.0 discusses the data quality objectives (DQOs) for the GPT.
- Section 3.0 describes the measuring and testing objectives for the GPT and describes the geophysical system types and proposed survey line locations.
- Section 4.0 details the geophysical measurements and equipment to be used during the investigation.
- Section 5.0 describes survey line designations, data handling, and processing methods.
- Section 6.0 describes the schedule and report preparation that will document the results of the GPT.
- Section 7.0 provides references to sources of information used in the preparation of this GPTP.

# 2.0 Data Quality Objectives

The United States Environmental Protection Agency (EPA) DQO process was followed to assist with systematic planning of the proposed GPT program. The DQO process is EPA's recommended planning process when environmental data are used to select between two alternatives or derive an estimate of contamination (EPA 2001). The DQO process is used to develop performance and acceptance criteria that clarify study objectives, define the appropriate type of data, and specific tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions. Performance criteria apply to new data collected for the project, while acceptance criteria apply to existing data proposed for inclusion in the project.

The DQO process, as described in EPA guidance, involves the following seven steps (EPA 2006):

1. Define the problem.
2. Identify the goal of the study.
3. Identify information needed for the study.
4. Define the boundaries of the study.
5. Develop the measurement approach.
6. Specify the performance or acceptance criteria.
7. Develop the plan for obtaining data.

A summary of steps 1 through 6 is provided in this section. The pilot test plan details as required in step 7 are described in Sections 3.0 through 5.0 of this GPTP.

## 2.1 Problem Statement

The on-site portion of the NERT RI Study Area (NERT On-Site Study Area) (**Figure 1**) has been the location of industrial operations since 1942 when it was developed by the United States government as a magnesium plant to support World War II operations. Following the war, this area continued to be used for industrial activities, including production of perchlorate, boron, and manganese compounds. Former industrial and waste management activities conducted at the NERT On-Site Study Area, as well as those conducted at adjacent properties, resulted in contamination of environmental media, including soil, groundwater, and surface water. Since 1979, the NERT On-Site Study Area has been the subject of numerous investigations and removal actions. Soil removal actions were conducted in 2010 and 2011 from the NERT On-Site Study Area to minimize potential health risks from impacted soil. Additional soil removal was performed in 2013 when the east end of the Beta Ditch was excavated. The soil removal activities and post-removal conditions are described in detail in the Revised Interim Soil Removal Action Completion Report (ENVIRON 2012). Subsequent soil removal at the Beta Ditch is reported in a separate report (ENVIRON 2014a). On-site groundwater removal actions include the installation of the Groundwater Extraction and Treatment System, designed to capture and treat perchlorate and hexavalent chromium in shallow groundwater.

In the spring of 1999, Southern Nevada Water Authority hydrologists discovered a seep discharging to the LVW at approximately 400 gallons per minute. Perchlorate concentrations in the seep exceeded 100,000 micrograms per liter (µg/L). The results of the seep samples indicated that a significant mass flux of perchlorate was entering the LVW; Kerr-McGee subsequently implemented a capture system in November 1999 to reduce the migration of perchlorate to the LVW (ENSR 2005). Groundwater seep samples in the LVW were collected in April 2000 by Kerr-McGee before the installation of the weirs installed perpendicular to the east-west course of the wash. Concentrations of perchlorate reported in the 2000 seep samples were reported up to 57,000 µg/L (location KM70; approximately river mile [RM] 6), and were highest near the seep discovered by SWNA. Upstream samples above location KM70 were either non-detect or very low (31 µg/L at KM58; near the Duck Creek confluence). Downstream seep concentrations dropped from KM70 with distance downstream to KM53 (321 µg/L; approximately RM 5), but increased at KM91 (2,100 µg/L; approximately RM 4.7). Concentrations in the seeps again decreased with distance downstream from KM91.

Subsequent hydrogeologic investigations revealed paleochannels, down-cut into the top of the Muddy Creek Formation and filled with coarser-grained alluvial fan deposits, were a primary mechanism of transport of perchlorate to the LVW. Geophysical studies have been conducted within and north of the Downgradient Study Area to evaluate the location of the paleochannels with some success, but additional evaluation is required to refine and improve the interpretation of channel geometry.

<u>Identify the Goals of the Study:</u>

- What geophysical methodology returns the most accurate interpretation of paleochannel geometry?
- Can geophysical data be verified with existing or new soil boring data?
- What geophysical method(s) can readily be implemented considering restrictions on access to property and biologically sensitive areas?
- Can the geophysical data identify and segregate coarse- and fine-grained sediments within the overlying alluvial fan deposits?

## 2.2 Identify the Information Inputs

Information required to answer the study questions will include existing field data, new geophysical data, and confirmatory boring data to be obtained during the planned GPT.

Existing geophysical data were collected by GeoVision and Willowstick. Three geophysical investigations have taken place in or adjacent to the Downgradient Study Area as shown in **Figure 2**. An electromagnetic investigation was undertaken in 2003 (GeoVision 2003a) covering the Basic Management, Inc. (BMI), Upper and Lower Ponds and Ditches Area south of the Downgradient Study Area (**Figure 2**). Additional geophysical data have been collected with electromagnetic surveys at five locations along the LVW in 2003 (GeoVision 2003b) and with the Aquatrack™ system in 2005 (Willowstick 2005) over a 950-acre area immediately north of the eastern portion of the Downgradient Study Area (**Figure 2**). Where available, existing soil boring logs were reviewed to assess the results of the existing geophysical surveys.

The proposed GPT will provide geophysical data for three geophysical systems discussed in Section 2.4. In addition boring logs from confirmation soil borings drilled along the GPT survey lines will be used in conjunction with the historical data to provide a more refined view of the subsurface conditions, including the location and geometry of paleochannels. This site-specific understanding of how the three different geophysical systems tested will provide an improved representation of subsurface conditions that will be used to help develop the DQOs for future full-scale geophysical investigations that will be incorporated into expanded groundwater investigations in the Downgradient Study Area.

## 2.3 Define the Study Area Boundaries

Step 4 of the DQO process is to define the boundaries of the study area. The boundary of the Downgradient Study Area is shown on **Figure 1** and includes an approximately 3.5-mile stretch of the LVW. The GPT survey lines will be located between 500 and 1,600 feet south of the LVW as shown on **Figure 3**.

## 2.4 Develop the Analytic Approach

Step 5 of the process involves designing the approach to answer the questions and achieve the GPT goals. Quality assurance/quality control (QA/QC) is considered during the design process.

The approach for this pilot test includes review of existing information and field evaluation of three surface geophysical systems to answer the study goals identified in Section 2.1. Currently, the locations and shapes of the paleochannels are inferred from existing boring logs and previous geophysical investigations across the NERT RI study areas, including the Downgradient Study Area (**Figure 2**). Additional geophysical surveys are proposed to help define the location and depth of these paleochannels near the LVW. The two previous electromagnetic surveys (GeoVision 2003a and 2003b) employed Time Domain Electromagnetics (TDEM), which requires transmitter loop sizes as large as 80 meters (262 feet) on each side of the survey line. Due to potential limited clear access in the Downgradient Study Area, two other geophysical systems, electrical resistivity and seismic, will be evaluated along with TDEM to determine which geophysical system(s) can meet the goals of the study.

Three previous geophysical investigations were reviewed to evaluate the quality of the data collected. Two employed TDEM and were conducted by GeoVision in 2003. The third investigation employed AquaTrack™ geophysical technology that uses Controlled Source –Frequency Domain Magnetics, and was conducted by Willowstick in 2005. To assess the results of the previous geophysical investigations, AECOM compared available soil boring data to the results of the various geophysical survey lines. A list of the wells and boring logs that were reviewed is included in **Appendix A**. The geophysical survey results along Line E, from the BMI Upper and Lower Ponds and Ditches investigation (**Figure 4)**, were compared to the lithological information from two nearby soil borings. Line E is located immediately south and east of the Downgradient Study Area. The TDEM-interpreted results from Line E showed good agreement with the nearby boring logs. The western portion of line G (**Figure 4**) is the closest portion of this geophysical line to the Downgradient Study Area. Along the western portion of line G, at boring LG027, the top of the UMCf identified from the soil boring does not match the top of the UMCf interpreted from the geophysical data. In the other portions of Line G there is good correlation between the soil boring data and the geophysical data. Assessment of the LVW geophysical survey (Lines 1 through 5) with soil boring data was not possible because there were no associated boring logs available for comparison (**Figure 2**). Also, comparison of Lines 1 through 5 with mapped paleochannels could not be made because these survey lines are oriented parallel to that of the paleochannels.

The AquaTrack geophysical investigation was used to characterize and delineate areas of greatest groundwater saturation and to help identify areas of elevated total dissolved solids (TDS) possibly associated with seepage from the upper and lower ponds and ditches. The AquaTrack geophysical technology uses Controlled Source – Frequency Domain Magnetics (CS-FDM). Low voltage, low amperage, and audio frequency electrical current (400 hertz AC signal) are used to energize the groundwater of interest. For the study, electrodes were placed in strategic well locations to facilitate contact with the groundwater. Because groundwater is a conductor, the electrical current concentrates in areas of high water content and in areas of elevated TDS. As the electrical current follows the groundwater, it creates a magnetic field characteristic of the injected electrical current (400 hertz signal). This unique magnetic field is identified and surveyed and recorded from the ground surface.

The AquaTrack investigation identified several areas of high groundwater saturation and TDS concentrations (i.e., preferential flow paths) within the survey area. In general, these high groundwater concentrations correlated with the 2003 GeoVision study and their interpretation of paleochannels. However, correlation of TDS concentrations was not conclusive throughout the study area. Overall, the magnetic contour maps generated from the AquaTrack study was useful to identify areas of greatest groundwater saturation and/or TDS concentrations, or both, but groundwater flow patterns were influenced by groundwater containing high TDS presumably emanating from the upper and lower ponds and ditches located on the BMI property.

A comparison of the interpreted preferential flow paths from the AquaTrack study and available soil boring logs indicated the preferential paths could not be verified by the soil boring logs. AquaTrack methods identify areas of high and low groundwater saturation and TDS concentrations, both properties that cannot be distinguished from soil boring logs. A comparison to two other GeoVision geophysical studies conducted in 2003 (for LVS and BMI Ponds and Ditches) to the AquaTrack study shows that interpreted paleochannels or preferential pathways are oriented in different directions. In addition, percolation of surface water (i.e., lagoons, wastewater treatment facility, and golf course) can influence magnetic signatures due to seepage, obscuring preferential pathways.

Since the AquaTrack methods and report do not provide data that can be used to determine the top of the UMCf, this system will not be tested as part of the GPT.

This goal of the GPT is to evaluate three geophysical systems to identify the system that returns the most accurate resolution of subsurface conditions. Verification of geophysical results is important to this evaluation. As such, existing information was evaluated to identify four potential locations for the GPT survey lines. Existing information consists of boring logs and previous geophysical investigations. The selection process of potential GPT survey lines included the following:

- Review of available boring logs within the Downgradient Study Area for lithological information, specifically for information that helps identify the depth to the top of the UMCf and the makeup of the overlying alluvial fan sediments. An important part of this review was the evaluation of the quality of available boring logs to see if sufficient details were provided to be used for verification of the geophysical data.
- Proposed GPT survey line is located over and across a portion of a previously Identified paleochannel.
- Considerations for access that included evaluation of property owners and surface conditions (i.e., biologically sensitive areas, generally in minimal vegetative-cover area, presence of structures, and ease of access).

Four potential locations for the GPT survey line were selected based on the review of available data and access considerations. Only two GPT survey line locations will be used for the testing of the geophysical systems. The GPT lines are located on U.S. Bureau of Reclamation and City of Henderson properties (**Figure 3**).

Each of the three geophysical systems will be used to conduct surveys over the two GPT survey lines. The geophysical subcontractor will record and interpret the data and present geophysical cross sections. The top of the UMCf should be identified by contrast in geophysical response to the two general geologic materials, the alluvial sediments and the more solidified fine-grained UMCf. Each of the proposed geophysical systems is briefly described below. A more detailed description of these systems is provided in Section 3.3.

- TDEM – evaluates lithologic conditions juxtaposing low electrical conductivity values for the alluvial fan deposits against higher conductivity values for the UMCf.
- Electrical resistivity – follows a similar formula by contrasting higher electrical resistivity values for the alluvial fan deposits and lower resistivity values for the UMCf.
- Seismic – evaluates subsurface conditions by contrasting the slower acoustic velocity in the alluvium against the faster acoustic velocity in the UMCf.

The geophysical results and interpretations will be compared with existing boring log data and additional borings will be installed along the GPT survey lines to support the interpretation and comparison of systems. These data will be used to assess the success of each system at achieving the study objectives.

## 2.5 Specify Performance or Acceptance Criteria

Step 6 of the process outlines the performance and acceptance criteria for the study. Major sources of uncertainty are identified and the measures taken to minimize the impacts of these uncertainties are defined. Uncertainty is always present in the measurement and interpretation of environmental data. In this case, the focus is on collecting and interpreting data to better characterize the location and morphology of the paleochannels.

In the absence of defined decision tolerance limits, the geophysical survey design should still strive to identify possible sources of error and minimize them, to the extent practical. The most significant type of error that may be encountered includes that of field geophysical measurements. Both random and systematic errors can be introduced during the physical collection of the measurements, survey line equipment setup, data analysis, and data handling.

All survey line setup and execution of the geophysical survey procedures will be performed by a geophysical subcontractor. GeoVision has been selected to perform the testing of the three proposed geophysical systems based on their proposed scope of work and cost estimate. GeoVision has previously conducted subsurface geophysical surveys in Henderson, Nevada, and specifically in the Las Vegas Wash area. It is expected that GeoVision will follow their company's standard operating procedures (SOPs) and Quality Assurance Program procedures, industry standards, including ASTM standards as appropriate, which include field procedures and applicable equipment calibration procedures. The following ASTM Standards will be used: ASTM D6429 and D6639 for the CSAMT and TDEM-based methods; ASTM D6431 for the resistivity-based method, and ASTM D5777 for the seismic reflection-based method. AECOM field personnel will confirm that the survey lines are correctly positioned and oriented. Utility clearance will be performed prior to surveys to identify metal or electrical objects that could interfere with the geophysical measurements and prior to any ground disturbance for the placement of probes into the ground.

This GPTP is for the evaluation phase of three geophysical survey systems that will be performed at two locations. A subsequent full-scale geophysical investigation will be conducted with the goal of mapping the location of paleochannels. Sampling density is not a consideration for the pilot test but will be during the full-scale investigation. The geophysical subcontractor will design, and adjust in the field, if necessary, the geophysical survey system layout to achieve the desired depth of investigation.

## 2.6 Develop the Plan for Collecting Data

Step 7 is detailed in the following sections.

# 3.0 Proposed Geophysical Pilot Test Locations and Systems

## 3.1 Geophysical Pilot Test Objectives

A full-scale geophysical investigation will follow this pilot test phase. The objective of the pilot test is to identify which geophysical methodology returns the most accurate interpretation of paleochannel geometry and the depth of the UMCf. Existing boring log data indicates that the top of the UMCf is encountered at an average of 35 feet below ground surface (bgs), ranging between 3 feet and 110 feet bgs, with nearly 90 percent of the boring logs encountering the UMCf at less than 55 feet bgs. As a verification of this interpretation, existing and new boring logs will be used as reference for the top of the UMCf. Another consideration related to site conditions is what geophysical method(s) can readily be implemented considering restrictions on access to property and biologically sensitive areas. An additional objective will be to evaluate if the geophysical data identify and segregate coarse- and fine-grained sediments within the overlying alluvial fan deposits.

## 3.2 Potential Locations of Geophysical Pilot Tests

The GPT investigation will be conducted at two locations; however, two backup locations have been selected as shown on **Table 1** below in case access issues or logistics make one or two of the locations infeasible. The four potential GPT locations are shown on **Figure 3** and a close up of each of the four GPT locations are shown on **Figure 6** If there is electromagnetic interference at any of the GPT line locations, the line would be moved away from the interference or the location would be rejected and an alternate location would be chosen. The proposed GPT survey line locations were selected based on three criteria: 1) the presence of previous boring location(s) with available log(s); 2) the line crosses a portion of a paleochannel; and 3) the location, in general, has minimal vegetative-cover. The first two criteria are paramount to the investigation, and the third is related to potential biologic disturbance and property owner access issues.

If property access is granted for all four locations, the two preferable locations (GPT-1 and GPT-2) will be selected for the investigation. GPT-1 and GPT-2 are the preferred locations, because they are the closest to the LVW and they represent areas where differences in the makeup of the alluvium may be encountered, they cross at least one existing boring location, and cross at least one presumed paleochannel pathway. If there is electromagnetic interference at any of the GPT line locations, the line would be moved away from the interference or the location would be rejected and an alternate location would be chosen.

According to the preliminary field biologic surveys that AECOM performed in February and March 2016, biologic constraints were not identified at the four potential GPT locations. Notifications to landowners and permitting as needed would be completed prior to conducting the geophysical surveys. If the USBR permitting process delays the schedule significantly, an alternate pilot test line would be selected. As the initial step in siting the line locations, boring and well locations were posted on an aerial map showing the currently inferred locations of the paleochannels. All four potential GPT locations have at least one boring with an available boring log, cross at least one paleochannel, and are in open, low-vegetation areas, as seen in recent aerial photography. The Chimera Golf Course and associated housing, and the subdivision adjacent to and west of the golf course have been excluded from consideration due to the high density of electromagnetic interferences associated with these developments.

| Table 1: Potential Pilot Test Survey Locations and Details | | | | |
|---|---|---|---|---|
| **Pilot Test Location ID** | **Land Owner (1)** | **Well / Boring Log ID (2)** | **Depth to top of UMCf in feet (2)** | **Boring Log Available? (3)** |
| GPT-1* | Bureau of Reclamation | MCF-29A | 62 | N |
| | | MCF-29B | 62 | N |
| | | HMW8 | 45 | Y |
| GPT-2* | City of Henderson Landfill | LBH-1 | 47 | N |
| | | MW-01 | 45 | Y |
| | | MW-02 | 7 | N |
| GPT-3 | Clark County Wetlands Park | PC-74 | 56 | Y |
| | | PC-76 | > 20 | Y |
| GPT-4 | Clark County Wetlands Park | MFC-08A | 68 | Y |
| | | MFC-08B | 53 | Y |
| | | MFC-08R | 39 | N |

Notes:

* Preferred GPT location.

(1) The property owners are based on the Figure 3 Land Ownership Jurisdictional Management and GPT Lines.

(2) Well / Boring ID and depth to top of UMCf information based on information provided in database titled "14.01.31 MASTER January 2014_All Wells DBase_edited Broadbent.xls".

(3) Boring log availability based on AECOM's inventory of boring logs listed in **Appendix A**.

## 3.3 Proposed Geophysical Systems for Evaluation

Three geophysical systems will be evaluated at each location unless site conditions preclude the use of one of the systems. For instance, there may only be a relatively narrow area along the survey line that is clear of electromagnetic interference. This could encumber the use of TDEM due to the space needed for its wide transmitter coil. The technical approaches that GeoVision will be implementing and SOPs for seismic systems are provided in **Appendix B**. The three geophysical systems to be evaluated include:

Electrical (Direct Current) Resistivity Investigation (ERI):

- ERI is a geophysical method in which an electrical current is injected into the ground through electrodes and voltages are measured at other surface electrodes. These measurements indicate the direction and amount of current flow in the subsurface. The recorded data is used to create a geoelectric model to represent the variation of apparent resistivity across the section. This section is then interpreted to relate apparent resistivity to subsurface geology. The penetration depth of ERI is ¼ to 1/5 of the profile length.

Seismic:

- Seismic Refraction (SR) method requires three components including a controlled shot of seismic energy (the source), sensors (geophones) to receive the energy, and a seismograph connected to a recording device to record the data. The seismic energy is refracted along geologic material boundaries back to the geophones along the survey line. Seismic refraction is commonly used to map the depth to bedrock and bedrock topography. The penetration depth for SR is ¼ the profile length.

- Multichannel Analyses of Surface Waves (MASW) is a seismic method where the stiffness of the ground is evaluated, primarily for geotechnical engineering purposes. In general it utilizes the same setup as for seismic refraction.
- Refraction Microtremor (ReMi) is a passive seismic method that utilizes background vibrations as the energy source and surface waves are recorded by the seismograph. This method is used for shear wave profiling and to confirm MASW results (confirms bedrock is not a caliche layer). The penetration depth of MASW/ReMi is 1/3 to ½ the profile length.
- The seismic equipment being utilized is capable of performing all of the three above techniques in the field, validating the results in real time.

Electromagnetics:

- TDEM uses electric and magnetic fields that are induced by a transient pulse followed by measurement of the decay response to determine subsurface electrical properties. The penetration depth of TDEM is up to 100 feet.
- Previous geophysical surveys described in Section 2.4 employed TDEM and as shown in Figure 4. Results from this investigation showed that there is a great deal of color variation indicating variations in resistivity and interpreted results to a depth of 120 feet. This investigation employed 100-foot (~30 meter) loop sizes on a side. The loop sizes were determined in the field based on site measurements and ranged between 30 and 80 meters on a side. For the GPT, GeoVision will size the loops based on site conditions that will achieve the project objectives.

GeoVision will be provided the existing, nearby, boring log information prior to mobilization to help them conceptualize the subsurface and make preliminary system setup decisions. Geophysical activities for the Downgradient Study Area include laying out two approximately 470 feet to 825-feet long GPT lines and screening for potential electromagnetic sources such as buried pipes, electrical lines, or metal fencing. The length of the GPT line will depend on the system being tested, the spacing of the equipment used to record the data, and the field conditions. The line length and spacing will drive the depth of the survey as well as the resolution. The lengths chosen should allow the acquisition of geophysical data below the expected contact between the alluvium and the UMCf in the areas of interest. When the survey line locations are confirmed to be clear of electromagnetic sources a land surveyor will accurately position survey stakes for the two GPT lines with end stakes and internal stakes at 300-foot intervals. GPTs using each of the three geophysical systems will be conducted over both pilot test lines. For QC purposes, an additional GPT over a minimum 100-foot interval of one of the GPT lines will be conducted with each system. The GPT activities are described in more detail in Section 4.0.

## 3.4 Verification of Geophysical Data

The two GPT survey lines will be located across or close to where boreholes have been previously advanced. Two new borings are planned to be drilled along each GPT line to verify the geophysical results. The minimum drilling depth for each boring is 75 feet but this depth could be extended deeper if the geophysical results indicate “structures” of interest that need to be investigated at greater depth. The deepest depth to the top of the UMCf for the 10 boring logs listed in Table is 1 is 68 feet. rotary sonic drilling yielding continuous geologic borehole data will be employed. The borehole locations will be selected in consideration of access requirements and after reviewing the geophysical results so that the boreholes can explore areas of interest.

### 3.4.1 Soil Borings

Soil borings are expected to be advanced by rotary sonic drilling methods, based on previous experience with drilling in the alluvium and UMCf. rotary sonic drilling offers relative ease of use, speed, and presence of an outer casing in the drill tooling. A rotary sonic drill rig is expected to be able to penetrate gravels, cobbles, caliche, or other hard layers. The Field Guidance Document for the drilling and destruction of soil borings is included in **Appendix C**.

Rotary sonic drill rigs (including compact rotary sonic drill rigs) typically produce soil cores which are extracted from the metal drilling stem into plastic core bags and/or core boxes. The cores will be logged by the field geologist using the Unified Soil Classification System. Photographs to document the soils will be taken of the cores labeled with boring ID and depth interval. Soil cores will be stored at a secure location until boring logs are prepared and finalized. Once the boring logs are completed the soil cores will be disposed of per the procedures detailed in Section 4.4 Investigative Derived Waste Management.

# 4.0 Survey Procedures and Equipment

The geophysical systems, other data collection equipment and associated procedures are described in the following sections. Geophysical survey equipment will be provided by the geophysical subcontractor (GeoVision) for three geophysical systems, ERI, Seismic, or Electromagnetic. Grubbing will be conducted to provide clearance to lay out the GPT survey lines. Geophysical survey methods employed by GeoVision will be based on their technical approach, SOPs and ASTM standards. GeoVision's technical approach and SOPs are provided in **Appendix B**.

To maintain consistency in the methods applied in the field for this assessment, field activities will adhere to the procedures described in this document and the aforementioned ASTM standards.

## 4.1 Documentation Procedures

Records that will be generated during field work include field data sheets, photographic logs, equipment inspection/calibration records, and others as necessary. Units of measure for any field measurements and/or analyses will be clearly identified on the field data sheets as necessary. The AECOM Field Supervisor, or other appropriate person designated by the AECOM Project Manager, will review the field data to evaluate the completeness of the field records.

### 4.1.1 Field Data Sheets

Field data sheets will be completed by field personnel during geophysical survey activities. Most of the geophysical data will be recorded digitally and the geophysical subcontractor will document activities associated with the survey line setup and on-site conditions and observations that may influence the geophysical results. AECOM field personnel will document field conditions, subcontractor activities, and site conditions that may influence the geophysical results. Entries will be made in language that is objective, factual, and free of personal opinions or terminology that might later prove unclear or ambiguous. Entries will be made in ink, signed and dated and no erasures will be made. If an incorrect entry is made, the information will be crossed out with a single strike mark, initialed, and dated by the user. Photographs taken will be identified by number and a description of the photograph will be provided.

If deemed necessary by the AECOM Project Manager, electronic copies of the data sheets may be produced after the geophysical surveys have been completed and these will be provided in the technical report that presents the results of this assessment. Example field data sheets are provided in **Appendix D**.

### 4.1.2 Photographs

Digital photographs will be taken if necessary to supplement and verify information entered into field logbooks. For each photograph taken, the following will be recorded in the field logbook:

- Date, time, and location;
- Number and brief description of the photograph; and
- Direction in which the photograph was taken, if relevant.

If a number of photographs are taken during a task, general notes will be sufficient on the group of photographs taken, so long as the information outlined above can be inferred from the information provided for each photograph.

### 4.1.3 Electronic Data

Electronic data are generally derived from the automated geophysical data acquisition systems. Geophysical instruments are equipped with or connected to data recording devices which are then downloaded to computers for processing with software that performs various manipulations, identifications, and calculations of data. The geophysicist processing the data will follow accepted industry procedures for processing and, where needed, modeling of the data, to prepare the data for final plotting.

Data can be reported in either hard copy form or electronic form. The raw data typically remains in digital format. Plots of the data at various stages of the analysis can be prepared for inclusion in an attachment to the subcontractor's geophysical report.

All three geophysical systems will require data manipulation or reduction to be performed electronically, outside of the raw data produced by purchased instrumentation. The calculations performed by the processing software are complex and not easily performed 'by hand'. These software programs are commercially available and follow industry standards.

## 4.2 Instrument Calibration Procedures

The geophysical equipment used for the GPT will be supplied by the geophysical subcontractor. They will be responsible for maintaining manufacturer recommended maintenance and calibration, and conducting any field calibration during equipment set-up each day. ASTM Standards will be followed including ASTM D6820-02 for TDEM methods, ASTM D6431 for Resistivity, and ASTM D7128 for SR method.

## 4.3 Equipment Cleaning Procedures

None of the geophysical equipment will come in contact with the groundwater or contaminated soil; therefore, no cleaning or decontamination is required. Confirmation boreholes drilled during the GPT will follow AECOM SOPs for drilling, decontamination, and associated tasks.

## 4.4 Investigation-Derived Waste Management

In general, investigation-derived waste (IDW) for a surface geophysical survey will consist of used personal protective equipment (disposable nitrile gloves) and household trash such as used paper towels, etc. This IDW will be double-bagged in plastic trash bags and will be disposed as municipal trash.

Vegetative waste generated by grubbing along the GPT survey lines will be handled based on the property owner requirements. It could be left in place, removed as inert materials or there may be requirements to containerize the waste and potentially sample and analyze it for waste disposal.

Cuttings generated from drilling of boreholes will utilize relevant procedures for handling drilling generated IDW as specified in the NERT Field Sampling Plan (ENVIRON, 2014b). The soil cuttings will be contained in 55-gallon steel drums or other appropriate containers. Drums or containers will be sealed and labeled "Pending Analysis" until analytical data of the soil cuttings is obtained. Labels will include the contents of the container (e.g., soil cuttings, decontamination water), the origin of the material (e.g., NERT RI Downgradient Study Area soil sampling), the date(s) the IDW was generated, and a contact phone number for the Generator of the material (NERT). IDW containers will be stored in a secure area of the property that has been designated for the storage of IDW. Decontamination water will be disposed of in the GW-11 pond located at the On-site NERT property. The Field Guidance Document for IDW management is provided **Appendix C**.

## 4.5 Geophysical Pilot Test

### 4.5.1 Pre-field Activities

A site-specific HASP has been developed for the Downgradient Study Area and the planned field work, including the geophysical surveys.

Access to properties for the GPT lines will be obtained by AECOM. Property owners will be contacted to obtain permission for access to conduct the geophysical surveys, and possible vegetation grubbing and drilling. Once access is obtained, NDEP, EPA, NERT, and property owners will be notified of the geophysical survey field schedule. A field reconnaissance of the GPT locations will be conducted to verify the location, accessibility, and physical conditions along each 825-foot long survey line.

A study of existing subsurface utilities will be conducted prior to final selection of the GPT survey lines to avoid crossing or being in close proximity of any subsurface utilities. As an additional step a utility clearance geophysical survey, with a magnetometer or similar device, will be conducted along the two GPT survey line locations. If metallic or electrical-related objects are identified along or crossing the survey lines during the utility clearance, the GPT line location would be adjusted or moved to another location to avoid potential impacts to subsurface utilities or interference with geophysical survey data collection. If needed, all or part of the survey lines will be cleared of vegetation so that the geophysical survey line equipment can be laid out and the survey measurements obtained. The various electrodes and geophones must be inserted into the ground and are connected by wires to the control and recording equipment. It is anticipated that clearings along the survey lines need to be at least six feet wide. After the final survey line locations are cleared of vegetation, land surveyors will accurately position the stakes along the survey line.

The GPT line positions and ground surface elevation will be surveyed by a State of Nevada licensed land surveyor. Locations will be referenced to the State Plane Coordinate System and elevations will be referenced to the North American Datum of 1983 Nevada East Zone (2701) with vertical datum based on NAVD 88 referenced to the City of Henderson Benchmark network. The end points and 50-foot intervals will be staked and surveyed, and labeled as described in Section 5.1. A table of the GPT line coordinates will be provided to NDEP and NERT as part of the GPT Tech Memorandum.

### 4.5.2 Field Activities

As described in Section 3.0, the GPT will be conducted at two locations with three geophysical survey systems, ERI, Seismic, and Electromagnetic. The three geophysical systems to be tested are active systems meaning that an energy source is employed and measurements are made by associated receiving equipment. The ERI system uses current electrodes to impart an electrical current into the ground and potential electrodes to measure the resulting voltage. Seismic system uses a single energy source, such as a sledgehammer blow to a steel plate lying on the ground, and a string of geophones to record the resulting refracting energy. Electromagnetic systems use a transmitter loop to transmit electromagnetic wave into the ground and a receiver loop to receive the secondary electromagnetic field.

After processing, the geophysical results, based on the characteristics of the energy return measurements, are interpreted as to their relationships to the local subsurface geology. Each system has data recording devices from which raw data can be downloaded for processing. The technical approach, SOPs and quality assurance manual that GeoVision will be implementing are described in detail in **Appendix B**. The geophysical subcontractor will perform the GPT surveys with the equipment they supply and will be responsible for the conduct of the survey. The geophysical subcontractor may need to adjust the geophysical survey setup, such as electrode spacing, to achieve optimal results. The geophysical subcontractor will also record daily activities and notes on survey setup and any field conditions that may impact the survey recordings. AECOM personnel will observe all field activities and will record field observations and, if necessary, photograph activities and site conditions. AECOM field data sheet for the GPT are included in **Appendix D**.

### 4.5.3 Quality Control Measurements

As part of the QC measures, each geophysical system will conduct a duplicate section over a single array length to that used during the 500-foot long survey that will cover a minimum interval of 100 feet of one of the proposed pilot test lines. The geophysical subcontractor will determine which portion of each pilot test line they will conduct the QC line for each system employed. Determination of where the QC line will be run will be similar to the procedure for collecting a “duplicate” sample for an analytical sampling program where a second sample is collected immediately after the main sample is collected. The duplicate QC line will be collected immediately after data is collected from a particular system. This QC line will provide a replicate section for comparison to the primary line, and serve as a QC for the proposed program. An additional element of QC is the comparison of boring log geologic information with the geologic layer interpretation of the GPT results. This is one of the elements that will be used to evaluate the success or failure of each system – to most accurately identify the depth to the top of the UMCf.

### 4.5.4 Verification Borehole Drilling

Two verification boreholes are planned to be drilled at each GPT survey line to confirm the geophysical data collected from the three systems. After reviewing the geophysical results, the two borehole locations will be selected at each of the GPT survey lines to verify geophysical data. If a GPT line has to be moved away from a proposed location due to utilities or access issues and there are no nearby existing borings, up to two additional borings may be proposed. A map showing the proposed verification borehole locations for each GPT survey line will be submitted to NDEP for their information.

The soil boreholes will be drilled using rotary sonic drilling methods as described in Section 3.4.2. The Field Guidance Document for the drilling and destruction of soil borings is included in **Appendix C**.

# 5.0 Measurement Station Designation, Data Handling and Analysis

In general, field survey personnel and geophysical subcontractors will conduct surveys and process data in a manner to maximize data quality. Data collected by the subcontractor will be field checked to ensure the data was recorded, saved, and of sufficient quality for further analysis. Identification of survey points are important elements that will be utilized to ensure data collected characterize site conditions. All survey points will be properly identified and site and test conditions recorded. The following sections discuss the station identification and QC nomenclature in detail.

## 5.1 Station Identification

The two preferred GPT survey lines will be referred to as GPT-1 and GPT-2. The geophysical system (ERI, Seismic, or Electromagnetic) being employed will be included in the station identification number. The station numbers along each survey line will be between 0 feet and 825 feet. For example, the station identification (ID) for a station point at 135 feet on GPT-1 collecting data using the ERI system will be identified as GPT-1-ERI-135. The station IDs will be entered onto field forms, logbooks, and other records documenting the geophysical survey activities.

### Field QA/QC Survey Identification Numbers

The geophysical QC surveys will be identified with similar nomenclature as the station ID; however, “QC” will be inserted after the survey line ID, for example, GPT-1-QC-ERI-95.

## 5.2 Station Labels

Both GPT survey lines will be staked at the beginning and ends of each line and at 50-foot intervals along the survey lines. The survey labels will be written on stakes in waterproof, permanent ink. The surveyor will locate each stake and label them per the convention described above. For example, the first stake will be GPT-1-0 and the last stake will be labeled GPT-1-500. The station label will be noted on all field observations related to the geophysical surveys.

If errors are made on a station label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

## 5.3 Borehole Identification

New borings drilled will be named according to the naming convention determined for this Downgradient Study Area investigation. Similar to the station identification discussed in Section 5.1, each borehole ID will be named in association with the pilot test survey line (GPT-1 or GPT-2) followed with “B” and its location along the pilot test survey line, for example GPT-1-B-135. At present there are not any plans to collect soil samples for analysis with the exception of IDW as discussed in Section 4.4.

## 5.4 Survey Data Handling and Transmittal

The geophysical subcontractor will record and download the recorded data for processing. If available, preliminary results will be provided to AECOM for review prior to leaving the filed. The geophysical subcontractor will process and plot the three sets of recorded data for the two GPT survey lines. These processed data, plots, and interpretations will be submitted to AECOM for review and comment prior to final submittal.

## 5.5 Field Observations

Field observations of field conditions by the geophysical subcontractor and AECOM personnel will be utilized during the analysis of the geophysical results. Observations will include features such as bike paths, nearby buildings, and temporary objects like an automobile that may have been present at one time and later moved. These objects could generate interference with the geophysical systems being used and adversely impact the recorded data. Other features include standing water and mobile objects such as trailers that could be temporary in nature along the survey lines. If an automobile parks near a GPT line during the field effort, AECOM personnel will attempt to have the vehicle moved.

### 5.5.1 Geophysical Data Processing Methods

The geophysical subcontractor will be responsible for processing the geophysical measurement data with the appropriate software for the geophysical systems utilized. The processing software will be 'off the shelf' standard software that meets industry standards. Geophysical data measurement and processing methods will be according to the geophysical subcontractor's SOPs and ASTM Standards.

## 5.6 Field QA/QC Procedures

The geophysical subcontractor will perform a field QC measurement for each system utilized along a single array length similar to that used during the GPT survey but no less than 100-foot long segment of one of the GPT survey lines. The position of the QC line will be with the agreement of the AECOM Project Manager. These measurements will be made to demonstrate the repeatability of the geophysical system measurements with some limitations. It is understood that there will be differences between the two sets of measurements (main survey line and QC line) due to potential differences in the positions of the geophones and electrodes, possible soil moisture differences, and air temperature changes. Part of the QC process will be that the subcontractor follows the same procedures throughout the process. Subcontractor field QC procedures will be conducted per the applicable ASTM standard and SOPs. The technical approach, SOPs, and quality assurance manual are included in **Appendix B**.

## 5.7 Data Verification

The geophysical data that is measured, processed, and plotted will be verified against boring log data from existing boreholes on or in close proximity to the GPT survey lines and with up to two new boreholes drilled on each of the GPT survey lines. The top of the UMCf will be identified from the geophysical data and compared to the existing interpretation of the top of the UMCf. The two data sets will be superimposed for comparison. If there are significant discrepancies between the geophysical results and the boring-log based information an evaluation will be conducted to reconcile the potential differences.

# 6.0 Schedule and Reporting

It is anticipated that the activities described in this GPTP will begin in early June 2016 after the scope of work and the GPTP has been approved by NDEP, EPA, and NERT, and stakeholders. After AECOM is granted access to the geophysical survey line locations, it is estimated that the GPT field activities will take approximately three weeks to complete.

The results of the geophysical surveys will be processed by the geophysical subcontractor. Draft results and plots will be provided to AECOM within two weeks of completing the field activities. Data from the verification borings will not be provided to the geophysical contractor prior to their final report preparation. AECOM will review the results and provide the geophysical subcontractor with questions or comments within one week. The geophysical subcontractor will finalize their report within one week of AECOM providing comments. During the same review period, up to two soil boring locations will be evaluated for each survey line. A map showing the locations of the proposed verification boreholes will be provided to NDEP and NERT prior to drilling activities. Drilling of the verification boreholes is expected to be completed four weeks after locations are selected. This schedule includes time to gain access to properties for ground-disturbing activities.

A map will be prepared showing the location of the GPT survey line locations and nearby boreholes. Figures showing the geophysical cross sections and boring log data will be prepared for each of the geophysical systems tested. Summary tables of the survey line station data will also be prepared.

A technical memorandum summarizing the results of this GPT will be prepared. The technical memorandum will include a brief description of field activities, the geophysical systems used, and a summary of data processing and interpretation of the results and maps. The technical memorandum will also include copies of the field data sheets, the final geophysical subcontractor report, new boring log data, and borehole data comparison with the geophysical section summary. A recommendation of the geophysical system to use for the full-scale geophysical investigation will also be included. The recommendation will be based primarily on the technical capabilities of the geophysical system. If technical capabilities are comparable between the various systems, selection will be based on cost. The technical memorandum is estimated to take 4 weeks.

A preliminary draft of the technical memorandum will be issued for review by NDEP, NERT, and EPA within approximately three weeks of receiving verification borehole data. Upon receipt of review comments, the technical memorandum will be updated; the Final Draft will be distributed to stakeholders for review. It is estimated that six weeks will be needed for review and comment by stakeholders.

A summary of the GPT tasks are provided below in Table 2.

**Table 2: Geophysical Pilot Test Tasks**

| Task | Approximate Schedule for Completion |
|---|---|
| Geophysical Pilot Test field activities | 4 weeks following mobilization |
| Geophysical subcontractor processes and plot Data | 4 weeks following completion of survey activities |
| Drill data verification boreholes | 3 weeks from preliminary geophysical results |
| Technical Memorandum preparation, review, and final document submittal. | 4 weeks from drilling of data verification boreholes |

# 7.0 References

ENVIRON International Corporation (ENVIRON). 2012. Revised Interim Soil Removal Action Completion Report, Nevada Environmental Response Trust Site, Henderson, Nevada, August 2010 – November 2011. January. Revised September 28. NDEP approved December 17, 2012.

ENVIRON. 2014a. Excavation of Beta Ditch at NERT-TIMET Property Line, Nevada Environmental Response Trust Site, Henderson, Nevada. March 31.

ENVIRON. 2014b. Field Sampling Plan Revision 1, Nevada Environmental Response Trust Site, Henderson, Nevada. July 18.

EPA. 2001. EPA Requirements for Quality Assurance Project Plans (QA/R-5). March.

EPA. 2006. Guidance on Systematic Planning Using the Data Quality Objectives Process (QA/G-4). February.

GeoVision. 2003a. Appendix 3G, Draft Interim Report Geophysical Investigation, BMI Upper and Lower Ponds and Ditches, Clark County, Nevada. May.

GeoVision. 2003b. Appendix A, Preliminary Draft Report Geophysical Investigation, Las Vegas Wash, Clark County, Nevada. June.

Willowstick Technologies, LLC. 2005. Basic Management, Inc. (BMI), Characterization and Delineation of Groundwater in Upper Unconfined Water-Bearing Zone between BMI Property and Las Vegas Wash, AquaTrack Geophysical Investigation, June.

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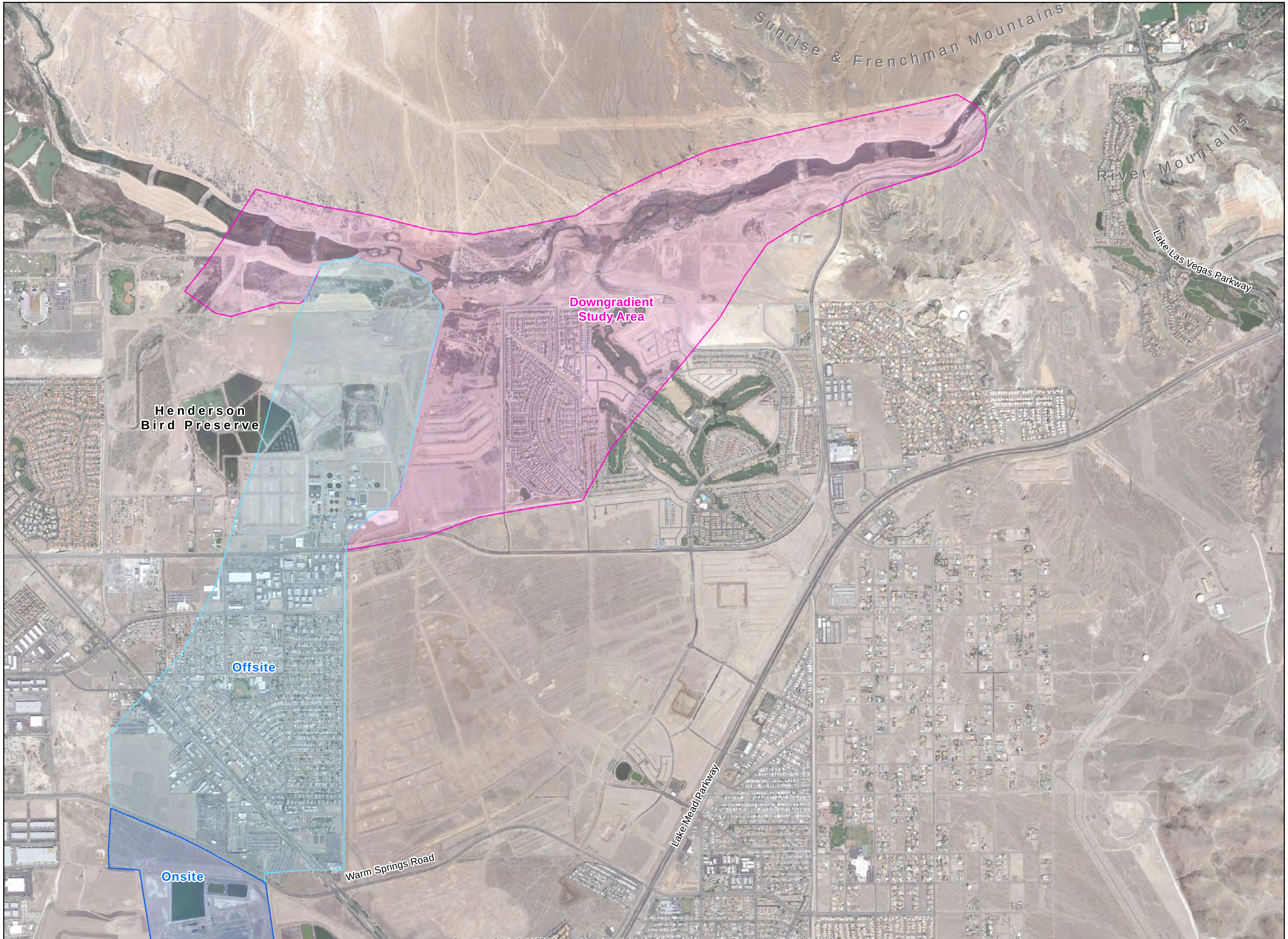
# Figures




OVERVIEW MAP


*Legend*

- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area

NORTH

0 2,000
Feet

Scale 1:24,000
1 inch = 2,000 feet



NERT
Remedial Investigation
Downgradient Study Area

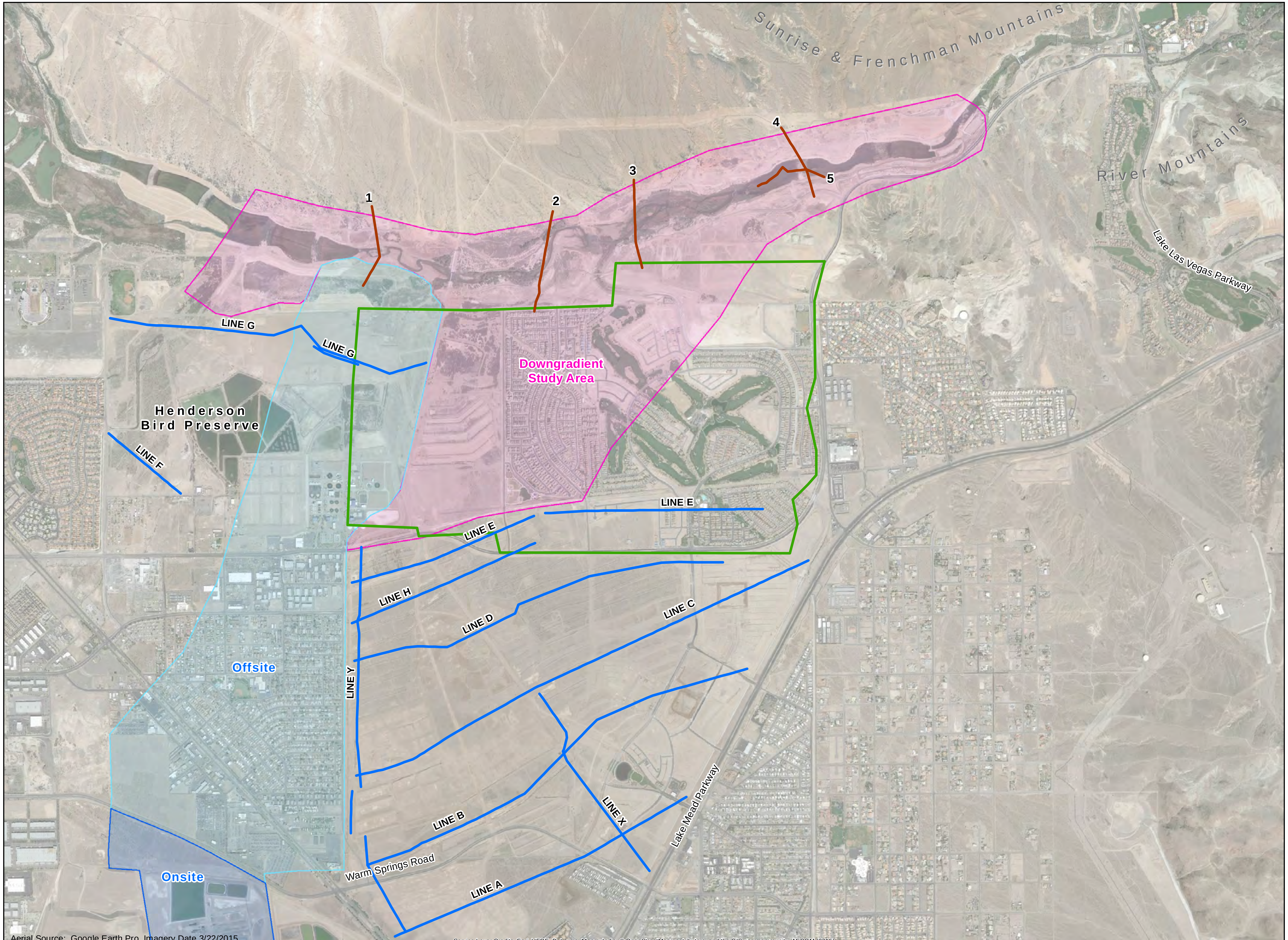
**DOWNGRADIENT STUDY AREA LOCATION MAP**

Date: 4/5/2016 Project: 60477365

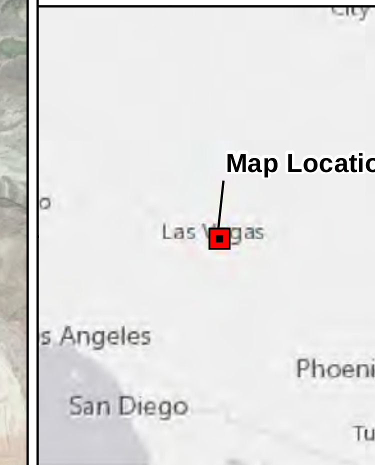
AECOM

**Figure 1**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Downgradient_Study_Area_20160229.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1




OVERVIEW MAP




***Legend***

- Las Vegas Wash Geophysical Survey - TDEM (GeoVision 2003)
- BMI Aquatrack Geophysical Survey - TDEM (Willowstick 2015)
- BMI Ponds & Ditches Geophysical Survey (GeoVision 2003)
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area

NORTH

0 2,000

Feet

Scale 1:24,000

1 inch = 2,000 feet



NERT
Remedial Investigation
Downgradient Study Area

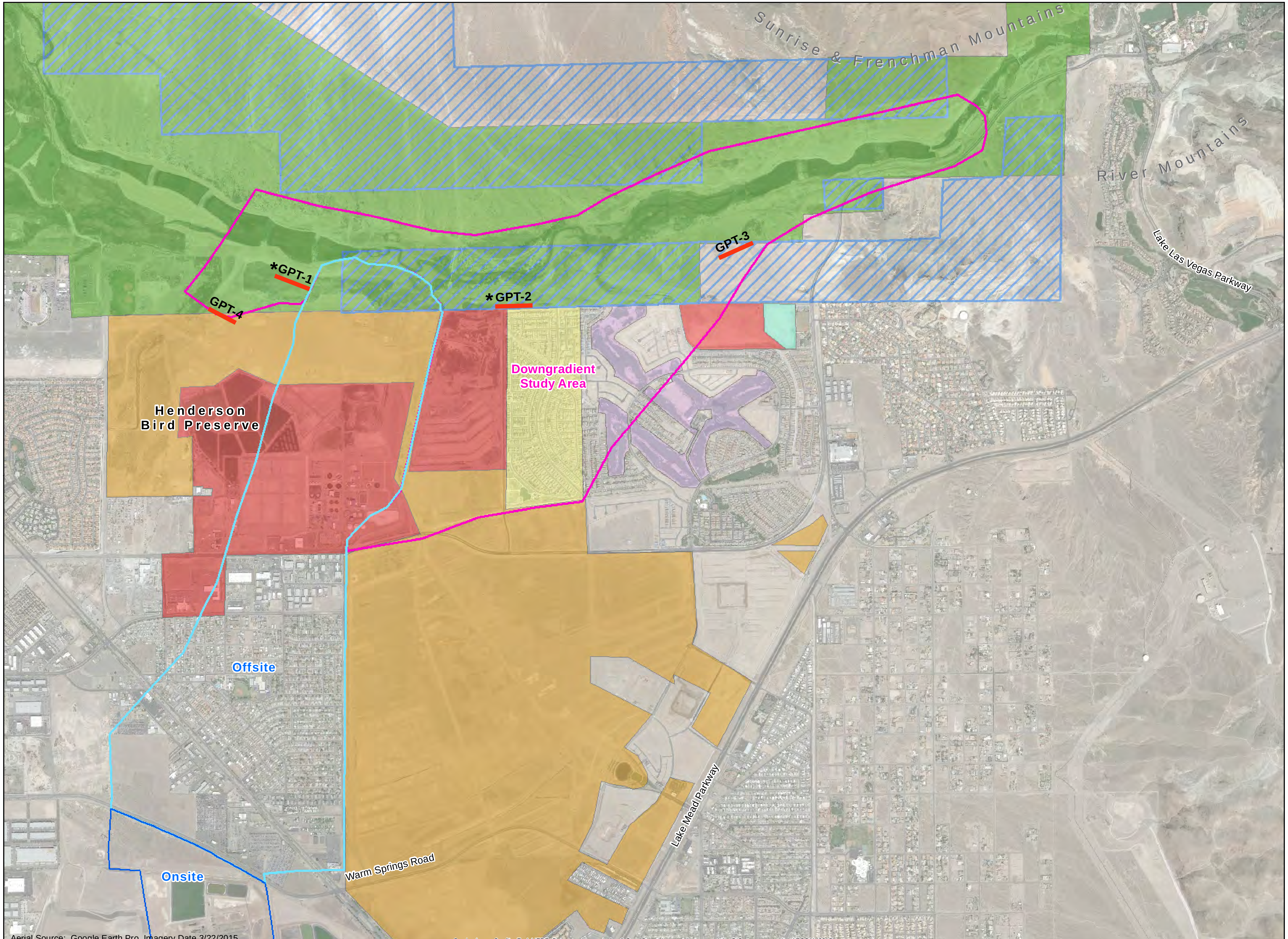
**PREVIOUS GEOPHYSICAL SURVEY LINE LOCATIONS**

Date: 4/5/2016 Project: 60477365

AECOM

**Figure 2**

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\02_Previous_Geophysical_Locations_20160405.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1




OVERVIEW MAP


**Legend**

- Potential Geophysical Pilot Test (GPT) Survey Line
- * Preferred GPT Survey Line
- NERT Downgradient Study Area
- NERT Off-site Study Area
- NERT On-site Study Area

**Land Owner**

- Land Well Company
- Clark County Wetlands Park
- City of Henderson
- Bureau of Reclamation
- Private Residences
- Chimera Golf Club
- School Board of Trustees

NORTH

0 2,000
Feet

Scale 1:24,000
1 inch = 2,000 feet



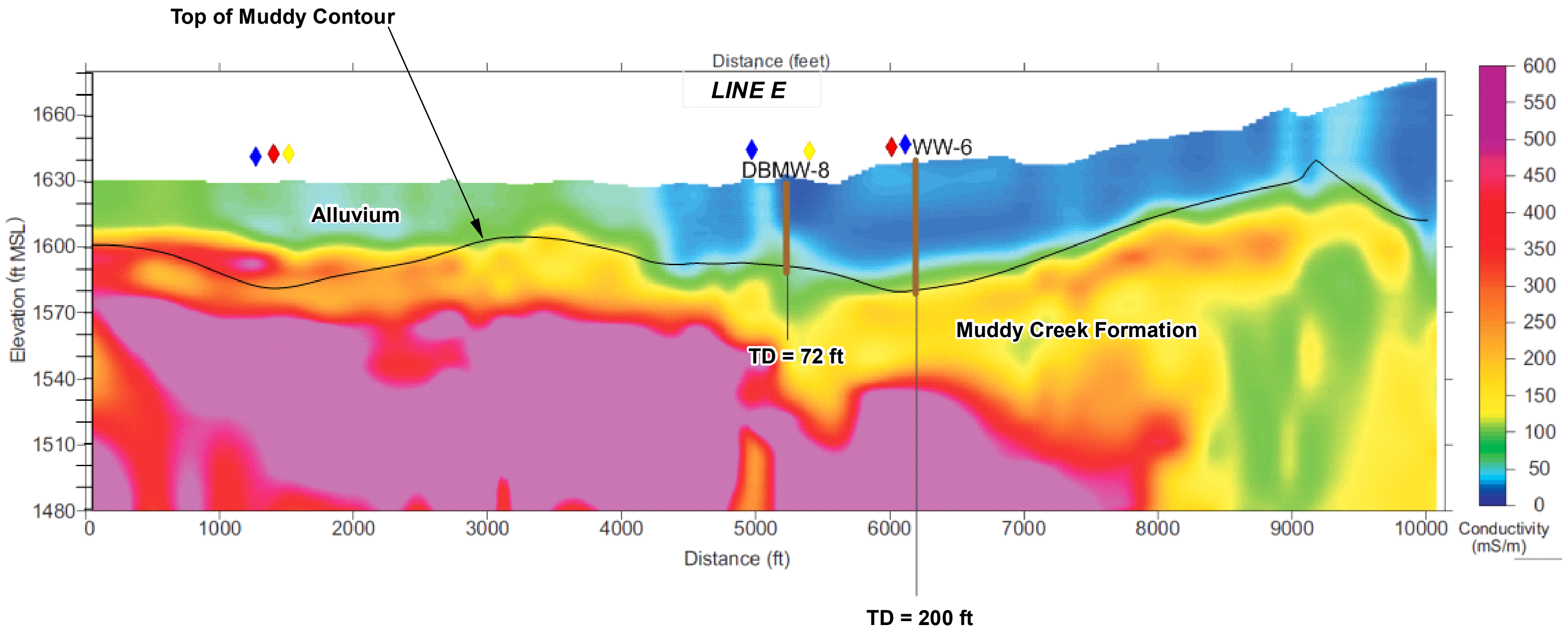
NERT
Remedial Investigation
Downgradient Study Area

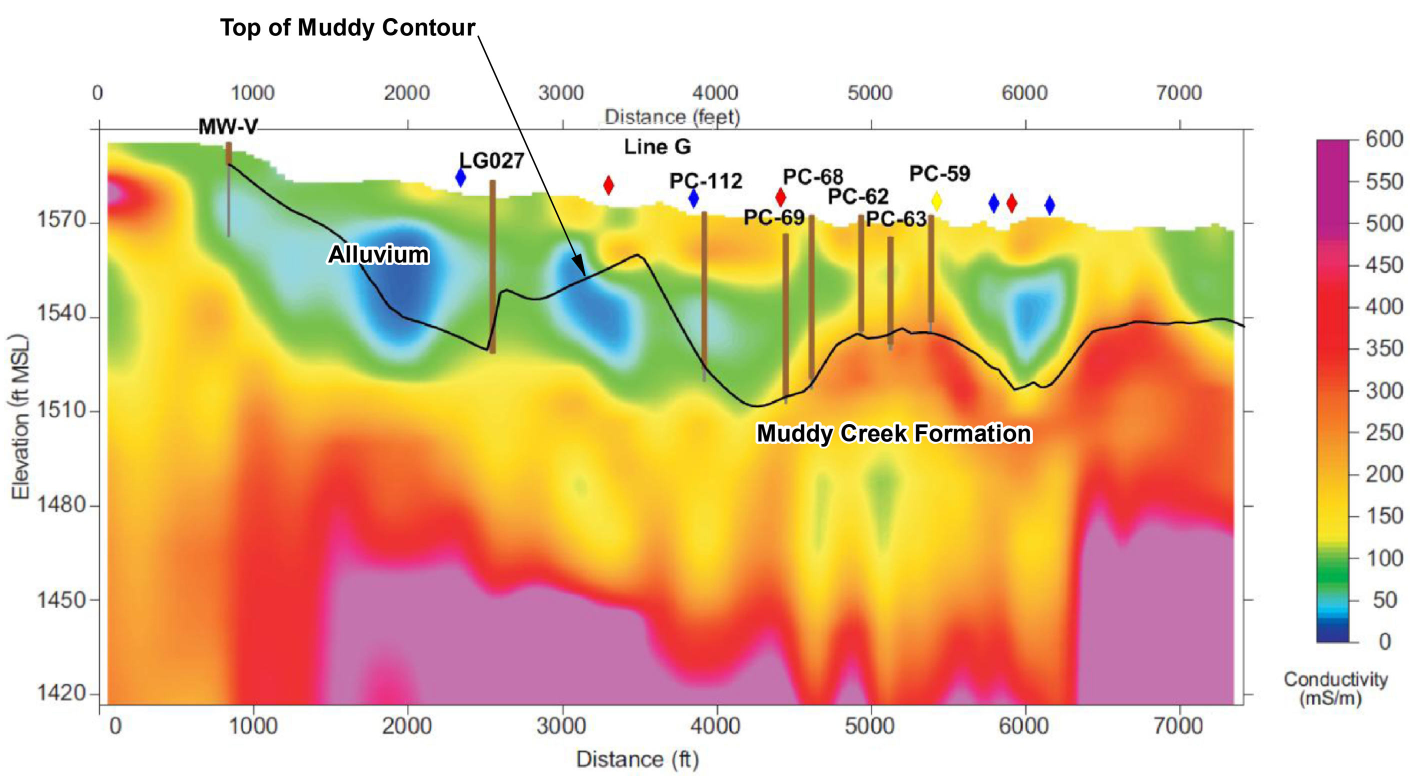
**POTENTIAL GEOPHYSICAL PILOT TEST SURVEY LINE LOCATIONS**

Date: 6/13/2016 Project: 60477365

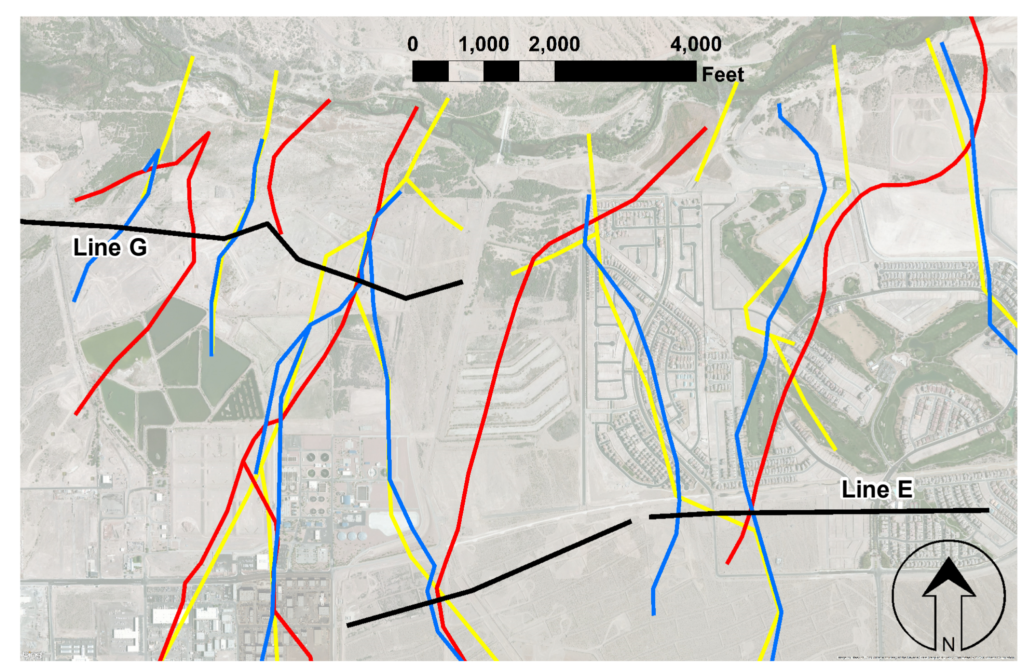
AECOM

**Figure 3**




**Geophysical Line Locations and Paleochannel Locations:**





***Legend***

Interpreted Paleochannel Location

WW-6 Soil Boring

Brown = Alluvium

Black = Muddy Creek formation



NERT
Remedial Investigation
Downgradient Study Area

**COMPARISON OF BMI LOWER AND UPPER POND GEOPHYSICAL SURVEY LINE WITH SOIL BORING LOGS**

Date: 6/20/2016 Project: 60477365

AECOM **Figure 4**

Source: Willowstick Technologies, LLC, 2005. Basic Management, Inc. (BMI), Characterization and Delineation of Groundwater in Upper Unconfined Water-Bearing Zone between BMI Property and Las Vegas Wash, Aquatrack Geophysical Investigation, June.

Service Layer Credits: Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

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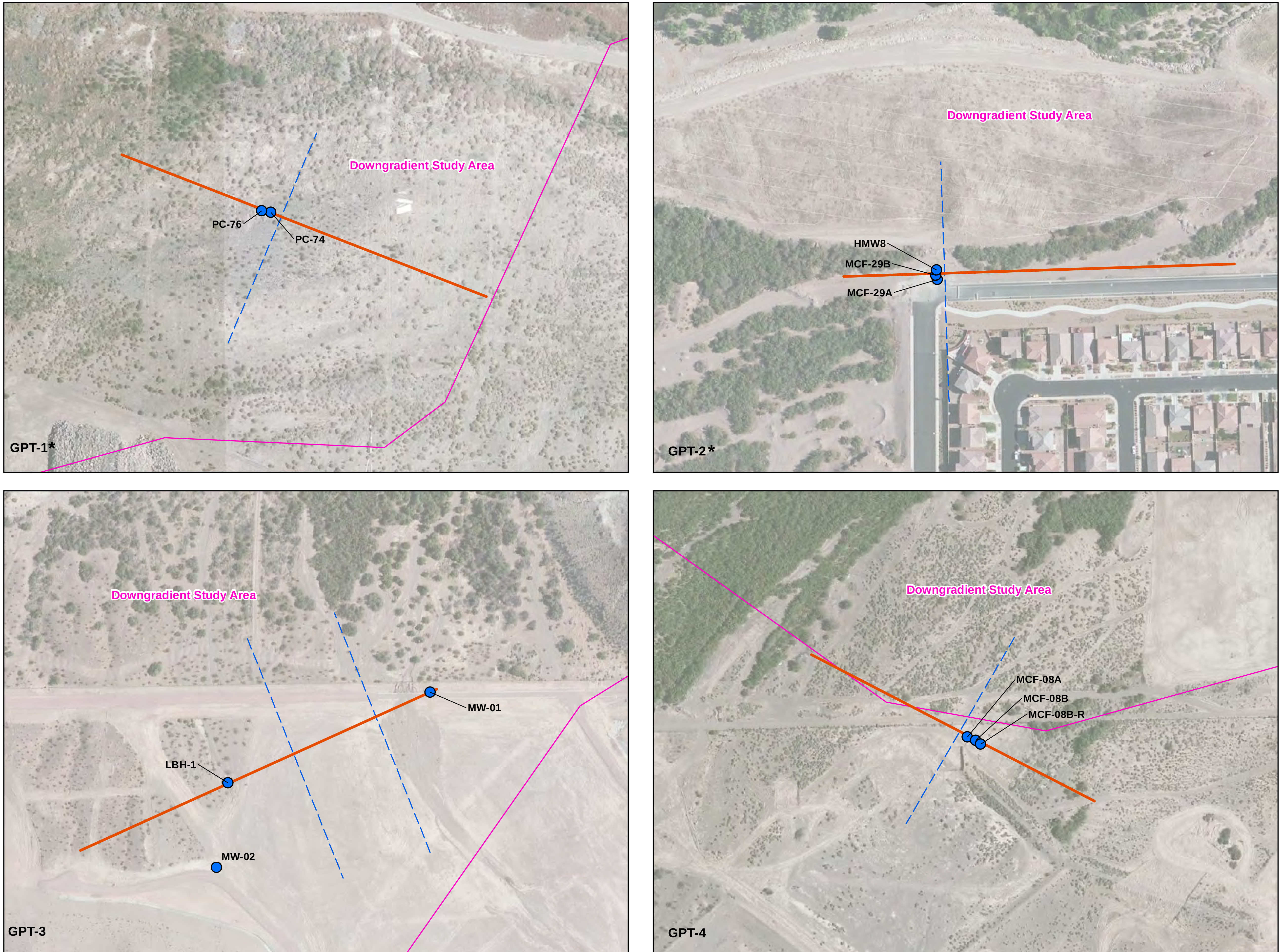



OVERVIEW MAP


*Legend*

- Potential Geophysical Pilot Test (GPT) Survey Line
- * Preferred GPT Survey Line
- Approximate Paleochannel Location
- NERT Downgradient Study Area Boundary
- Pilot Test Boring/Well Location

NORTH

0 200

Feet

Scale 1:2,400

1 inch = 200 feet



NERT
Remedial Investigation
Downgradient Study Area

## DETAILS OF POTENTIAL GEOPHYSICAL PILOT TEST SURVEY LINE LOCATIONS

Date: 6/13/2016 Project: 60477365

AECOM

Figure 5

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Path: J:\Client-Projects\NDEP\NERT_GW_RI\900-CAD\00-GIS\MXDs\Geophysical\05_Geophysical_closeup Locations_20160613.mxd | Coordinate System: NAD 1983 StatePlane Nevada East FIPS 2701 Feet | User: ScopM1

# Appendix A

# Summary of Available Data for Wells and Borings in Downgradient Study Area

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| 3KGBHSN | | 844266.22 | 26737806.99 | No Data | |
| AA-07 | | 837100.42 | 26729559.52 | -0.5 | |
| AA-08 | X | 827756.55 | 26733208.24 | 147 | BRC Dataset_27_MCF_BoringLogs |
| AA-10 | X | 825935.16 | 26730040.80 | -0.65 | BRC Dataset_27_MCF_BoringLogs |
| AA-18 | X | 836690.87 | 26727656.38 | 7.53 | BRC Dataset_27_MCF_BoringLogs |
| AA-19 | X | 832521.44 | 26727447.10 | 6.05 | BRC Dataset_27_MCF_BoringLogs |
| AA-20 | X | 831811.84 | 26728007.71 | 21.5 | BRC Dataset_27_MCF_BoringLogs |
| AA-21 | X | 826148.08 | 26734078.78 | 1.37 | BRC Dataset_27_MCF_BoringLogs |
| AA-22 | X | 833425.59 | 26731586.01 | 2.91 | BRC Dataset_27_MCF_BoringLogs |
| AA-23 | X | 834561.77 | 26732387.15 | No MCf | BRC Dataset_27_MCF_BoringLogs |
| AA-23R | X | 833898.96 | 26732042.31 | No MCf | BRC Dataset_46_DBMW_BoringLogs_2007 |
| AA-26 | X | 840176.49 | 26733349.15 | 10 | BRC Dataset_27_MCF_BoringLogs |
| AA-30 | | 836125.91 | 26733691.70 | 0 | |
| AAX-15 | X | 823068.13 | 26728783.01 | 20 | 2004.pdf |
| AAY-13 | X | 822018.10 | 26729808.20 | 28.5 | 2004.pdf |
| AC-01 | | 826465.98 | 26733350.08 | No MCf | |
| AC-02 | | 826592.83 | 26733354.43 | No MCf | |
| AC-03 | | 826559.94 | 26733446.79 | No MCf | |
| AC-04 | | 826651.83 | 26733436.15 | No MCf | |
| APEW-1 | | 825422.20 | 26729271.10 | 31 | |
| APEW-2 | | 825681.50 | 26729275.20 | 19.5 | |
| APEW-3 | | 827229.40 | 26729290.00 | 29.5 | |
| APX-10 | | 827736.69 | 26729302.95 | 10 | |
| APX-1-45 | X | 825255.70 | 26729255.10 | 36 | Book 2_2004.pdf |
| APX-2-45 | X | 825650.90 | 26729263.00 | 32 | Book 2_2004.pdf |
| APX-2-P1-16 | X | 825640.90 | 26729263.50 | 16 | Book 2_2004.pdf |
| APX-2-P1O1 | X | 825601.60 | 26729261.20 | 17 | Book 2_2004.pdf |
| APX-4-20 | X | 826451.20 | 26729275.10 | 26.3 | Book 2_2004.pdf |
| APX-5-16 | X | 827009.30 | 26729285.00 | 24 | Book 2_2004.pdf |
| APX-5-7 | X | 826987.80 | 26729285.20 | 2.5 | Book 2_2004.pdf |
| APX-7-14 | | 825193.10 | 26729254.30 | 8.5 | |
| APX-8 | | 827416.26 | 26729294.77 | 10 | |
| AREW-1 | | 823916.80 | 26727999.20 | 20 | |
| AREW-2 | | 824122.00 | 26728000.20 | 20.5 | |
| AREW-3 | | 824322.00 | 26728001.20 | 24 | |
| AREW-4 | | 824528.50 | 26728002.50 | 26.5 | |
| AREW-5 | | 824727.50 | 26728003.70 | 27 | |
| AREW-6 | | 824941.20 | 26728004.80 | 23.5 | |
| ARP-1 | X | 828593.16 | 26728365.51 | 5 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-2 | X | 828726.35 | 26728363.61 | 1 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-2A | X | 828722.80 | 26728404.34 | 0.5 | Field Log ARP-2A |
| ARP-3 | X | 828860.77 | 26728364.89 | 3 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-3A | X | 828856.20 | 26728402.86 | 0 | Field Logs ARP-3A |
| ARP-4 | X | 829171.79 | 26728363.72 | 8 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-4A | X | 829167.89 | 26728411.81 | 2.5 | ARP-4A |
| ARP-5 | X | 829395.34 | 26728452.84 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-5A | X | 829375.01 | 26728458.43 | 2.5 | ARP-5A |
| ARP-6 | X | 829531.51 | 26728496.99 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ARP-6A | X | 829514.78 | 26728480.20 | No MCf | ARP-6A |
| ARP-6B | X | 829520.52 | 26728499.92 | 1 | ARP-6B |
| ARP-7 | X | 829668.22 | 26728501.08 | 3 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-1 | X | 828543.96 | 26728122.71 | 5 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-1A | X | 828536.78 | 26728122.21 | 4 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-2 | X | 828625.03 | 26728084.71 | 2 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-2A | X | 828618.82 | 26728085.56 | 1 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-3 | X | 828775.42 | 26728085.17 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-3A | X | 828768.70 | 26728084.70 | 5 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-4 | X | 828850.69 | 26728085.26 | 4 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-4A | X | 828844.49 | 26728084.58 | 4 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-5 | X | 829369.98 | 26728128.79 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-6 | X | 829472.91 | 26728140.60 | 4 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-6A | X | 829478.83 | 26728140.79 | 4 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-7 | X | 829576.52 | 26728145.71 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-7A | X | 829582.79 | 26728143.19 | No MCf | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-7B | X | 829576.25 | 26728151.94 | 5 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-8 | X | 828697.72 | 26728084.10 | 3 | KMG ART-ARP Series Wells-Borings_3-2003 |
| ART-8A | X | 828691.89 | 26728083.31 | 6 | KMG ART-ARP Series Wells-Borings_3-2003 |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| ART-9 | X | 829525.57 | 26728143.32 | 5 | ART 9 lith log |
| AZ-1 | | 832810.41 | 26730276.72 | 6 | |
| AZ-2 | | 834669.87 | 26730357.17 | No MCf | |
| B-1 | X | 828417.50 | 26728049.50 | 12 | 2001 Borings B-1 to B-3 |
| B-2 | X | 828808.50 | 26728095.50 | 10.5 | 2001 Borings B-1 to B-3 |
| B-3 | X | 829209.90 | 26728102.80 | 12 | 2001 Borings B-1 to B-3 |
| B-4 | | 829599.10 | 26728133.50 | 12.5 | |
| B-5 | | 829209.95 | 26728070.86 | 7.3 | |
| B-6 | | 829219.22 | 26728071.17 | 24 | |
| B-7 | | 829448.04 | 26728078.32 | 8 | |
| B-8 | | 829456.63 | 26728079.61 | 22.5 | |
| B-9 | | 828942.00 | 26728095.00 | 7 | |
| B-10 | | 829508.00 | 26728080.00 | 2.5 | |
| B2-3 | | 830687.57 | 26729714.93 | No MCf | |
| B2-6 | | 831272.81 | 26729713.34 | No Data | |
| B2-8 | | 830616.01 | 26729344.19 | No Data | |
| B2-9 | | 830888.84 | 26729416.56 | No Data | |
| B2-9A | | 830879.06 | 26729417.13 | No Data | |
| B2-10 | | 831045.79 | 26729415.80 | No Data | |
| B2-11 | | 831402.45 | 26729472.44 | No Data | |
| B2-12 | | 830638.08 | 26728889.60 | No MCf | |
| B2-13 | | 830909.20 | 26728979.91 | No Data | |
| B2-14 | | 831123.49 | 26729069.33 | No Data | |
| BEC-10 | X | 835778.56 | 26727623.50 | 60 | BRC Dataset_22_BEC_BoringLogs |
| BEC-12 | X | 840870.00 | 26728991.00 | No MCf | BRC Dataset_22_BEC_BoringLogs |
| BMMW-2 | | 820648.00 | 26731103.20 | 16 | |
| CCI-1 | | 834123.60 | 26731430.70 | 5 | |
| CCI-2 | | 834388.30 | 26731467.00 | 3.5 | |
| CCI-3 | | 834941.50 | 26731428.70 | 11.5 | |
| CCI-4 | | 835328.70 | 26731544.60 | 32.5 | |
| CMMW-1 | | 824364.50 | 26728589.60 | 12 | |
| COH-1 | X | 832839.10 | 26734350.00 | 147.6 | CoH Alternate Discharge Geotech 2002 Boring Logs |
| COH-1A | X | 832839.10 | 26734355.00 | -1 | CoH Alternate Discharge Geotech 2002 Boring Logs |
| COH-2 | X | 832572.52 | 26733634.08 | 118.5 | CoH Alternate Discharge Geotech 2002 Boring Logs |
| COH-2A | X | 832549.34 | 26733644.43 | 0.4 | CoH Alternate Discharge Geotech 2002 Boring Logs |
| DBMW-1 | X | 830469.55 | 26727999.29 | 10 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-2 | X | 830530.28 | 26728059.44 | 5.5 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-3 | X | 831032.81 | 26728150.18 | 9 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-4 | X | 832295.98 | 26729903.30 | 15 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-5 | X | 833398.98 | 26729807.56 | 23 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-6 | X | 834409.61 | 26728947.31 | 11 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-7 | X | 835304.90 | 26729070.04 | 29 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-8 | X | 835406.87 | 26729027.21 | 29 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-9 | X | 836248.43 | 26727788.85 | 35 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-10 | X | 836955.59 | 26727918.57 | 15 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-11 | X | 837595.56 | 26727990.80 | 40 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-12 | X | 838000.97 | 26727975.84 | 45 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-13 | X | 838576.96 | 26727960.53 | 45 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-14 | X | 838987.26 | 26727957.62 | 29 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-15 | X | 839477.50 | 26727964.31 | 29 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-16 | X | 840514.78 | 26728557.03 | 15 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-17 | X | 840772.27 | 26728097.27 | 11 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-18 | X | 840571.34 | 26727750.53 | 18 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-19 | X | 831488.74 | 26731383.23 | 10 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-20 | X | 838723.25 | 26734838.71 | 18 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DBMW-22 | X | 839140.74 | 26733030.52 | 40 | BRC Dataset_46_DBMW_BoringLogs_2007 |
| DM4 | X | 830802.17 | 26728130.60 | 3 | DM-1 to DM-10.pdf |
| DM5 | X | 833187.20 | 26728698.75 | 3.5 | DM-1 to DM-10.pdf |
| DM7B | X | 837165.66 | 26727896.49 | 5 | DM-1 to DM-10.pdf |
| DM8 | X | 838790.56 | 26727795.18 | 2 | DM-1 to DM-10.pdf |
| DW-01 | | 831874.10 | 26728426.00 | 2 | |
| ESE7 | | 839673.67 | 26729007.03 | 5.5 | |
| ESE-B1 | | 840304.60 | 26731733.50 | 0 | |
| ESE-B2 | | 839248.60 | 26732341.80 | 3 | |
| ESE-B3 | | 837860.90 | 26731961.20 | 11 | |
| ESE-B4 | | 837933.90 | 26733340.70 | 0 | |
| ESE-B5 | | 836374.90 | 26731279.90 | 4.5 | |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| ESE-B6 | | 836559.20 | 26729551.70 | 4.5 | |
| ESE-B7 | | 839673.70 | 26729007.00 | 21.5 | |
| ESE-B8 | | 837684.30 | 26728298.90 | 5.5 | |
| EWQal-01 | | 0.00 | 0.00 | 10 | |
| EWQal-02 | | 0.00 | 0.00 | 24 | |
| EWQal-04 | | 0.00 | 0.00 | 17 | |
| EWQal-05 | | 0.00 | 0.00 | 12 | |
| EWQal-07 | | 0.00 | 0.00 | 13 | |
| EWQal-08 | | 0.00 | 0.00 | 21 | |
| EWQal-09 | | 0.00 | 0.00 | 13 | |
| EWQal-10 | | 0.00 | 0.00 | 19 | |
| EWQal-11 | | 0.00 | 0.00 | 10 | |
| EWQal-12 | | 0.00 | 0.00 | 19 | |
| EWQal-13 | | 0.00 | 0.00 | 15 | |
| EWQal-20 | | 0.00 | 0.00 | No Data | |
| EWQal-21 | | 0.00 | 0.00 | No Data | |
| EWxMCF-01 | | 0.00 | 0.00 | 23 | |
| EWxMCF-02 | | 0.00 | 0.00 | 4 | |
| EWxMCF-03 | | 0.00 | 0.00 | 32 | |
| EWxMCF-04 | | 0.00 | 0.00 | 37 | |
| EWxMCF-05 | | 0.00 | 0.00 | 18 | |
| EWxMCF-07 | | 0.00 | 0.00 | 36 | |
| EWxMCF-09 | | 0.00 | 0.00 | -7 | |
| EWxMCF-11 | | 0.00 | 0.00 | No MCf | |
| EWxMCF-01 | | 0.00 | 0.00 | 71 | |
| EWxMCF-02 | | 0.00 | 0.00 | 57 | |
| EWxMCF-03 | | 0.00 | 0.00 | 74 | |
| EWxMCF-04 | | 0.00 | 0.00 | 86 | |
| EWxMCF-05 | | 0.00 | 0.00 | 68 | |
| EWxMCF-07 | | 0.00 | 0.00 | 84 | |
| EWxMCF-09 | | 0.00 | 0.00 | 47 | |
| EWxMCF-11 | | 0.00 | 0.00 | 50 | |
| EWxMCF-14 | | 0.00 | 0.00 | No Data | |
| EWxMCF-15 | | 0.00 | 0.00 | No Data | |
| EWxMCF-16 | | 0.00 | 0.00 | No Data | |
| H-17B | | | | No Data | |
| HM-1 | | 833530.00 | 26731501.00 | No Data | |
| HM-2 | | 832199.20 | 26731069.80 | No MCf | |
| HM-3 | | 833470.00 | 26730105.00 | No Data | |
| HMW13 | | 827711.49 | 26731740.35 | 4 | |
| HMW14 | | 827174.04 | 26731535.30 | 0.02 | |
| HMW15 | | 827608.00 | 26729901.00 | 13 | |
| HMW16 | | 827090.00 | 26728531.00 | 16 | |
| HMW23 | | 835021.10 | 26734074.10 | No MCf | |
| HMW7 | | 834875.04 | 26733616.27 | 0.04 | |
| HMW8 | | 833956.44 | 26733456.69 | -0.01 | |
| HMW9 | | 833045.87 | 26733362.32 | 0.04 | |
| HSC-1 | | 829167.32 | 26733118.44 | 933 | |
| HSC-2 | | 830557.59 | 26733408.75 | 1270 | |
| HSC-3 | | 835538.40 | 26735919.80 | 830 | |
| HSC-4 | | 819601.00 | 26728499.00 | 2108 | |
| HSW-1 | | 832121.07 | 26730000.82 | No MCf | |
| HSW-2 | | 832608.20 | 26730007.65 | No MCf | |
| HSW-3 | | 833119.91 | 26731276.31 | 1 | |
| HSW-4 | | 833677.45 | 26730297.62 | No MCf | |
| HSW-5 | | 832558.02 | 26731059.01 | 3 | |
| HSW-6 | | 832831.78 | 26731107.28 | 1 | |
| L1001 | | 827216.00 | 26727863.00 | No Data | |
| L1002 | | 827211.00 | 26727870.00 | No Data | |
| L1003 | | 827202.00 | 26727869.00 | No Data | |
| L615 | X | 830280.21 | 26727856.50 | 10 | L series 615 to 631.pdf |
| L617 | X | 830105.32 | 26727862.30 | 9 | L series 615 to 631.pdf |
| L619 | X | 829913.43 | 26727855.48 | 20 | L series 615 to 631.pdf |
| L621 | X | 829704.79 | 26727855.49 | 20 | L series 615 to 631.pdf |
| L623 | X | 829534.69 | 26727856.30 | 14 | L series 615 to 631.pdf |
| L625 | X | 829351.63 | 26727855.36 | 16 | L series 615 to 631.pdf |
| L627 | X | 829147.14 | 26727855.42 | 286 | L series 615 to 631.pdf |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| L629 | X | 828965.24 | 26727851.34 | 10 | L series 615 to 631.pdf |
| L631 | X | 828743.75 | 26727840.82 | 9 | L series 615 to 631.pdf |
| L631T | X | 828696.88 | 26727746.52 | 9 | L series 615 to 631.pdf |
| L633 | X | 828491.72 | 26727840.25 | 15 | L series 633 to 676.pdf |
| L635 | X | 828302.28 | 26727839.46 | 115 | L series 633 to 676.pdf |
| L637 | X | 828110.00 | 26727839.47 | 10.5 | L series 633 to 676.pdf |
| L639 | X | 827905.58 | 26727838.22 | 13 | L series 633 to 676.pdf |
| L641 | X | 827709.47 | 26727836.08 | 7 | L series 633 to 676.pdf |
| L643 | X | 827511.16 | 26727836.05 | 10 | L series 633 to 676.pdf |
| L643T | X | 827473.38 | 26727731.08 | 5 | L series 633 to 676.pdf |
| L645 | X | 827310.03 | 26727833.00 | 17 | L series 633 to 676.pdf |
| L647 | X | 827105.86 | 26727830.13 | 6 | L series 633 to 676.pdf |
| L649 | X | 826903.00 | 26727824.75 | 5 | L series 633 to 676.pdf |
| L651 | X | 826708.65 | 26727828.14 | 8 | L series 633 to 676.pdf |
| L653 | X | 826510.59 | 26727825.34 | 6 | L series 633 to 676.pdf |
| L676 | X | 824194.88 | 26727814.73 | 6 | L series 633 to 676.pdf |
| LBH-1 | | 839018.89 | 26734657.27 | 0 | |
| LBH-2 | | 839566.65 | 26734136.94 | 0 | |
| LG009 | | 836000.00 | 26734572.85 | 22 | |
| LG010 | | 835989.58 | 26734562.44 | 0 | |
| LG011 | | 836768.23 | 26734184.83 | No MCf | |
| LG012 | | 836854.17 | 26734169.21 | No MCf | |
| LG015 | | 830725.10 | 26735214.10 | -1.2 | |
| LG016 | | 830725.70 | 26735115.80 | 18 | |
| LG017 | | 833420.30 | 26732682.70 | 46 | |
| LG018 | | 833367.70 | 26733108.00 | 0 | |
| LG019 | | 831713.10 | 26733097.80 | 25 | |
| LG020 | | 831697.10 | 26733292.00 | 0 | |
| LG021 | | 831479.80 | 26728495.40 | 10 | |
| LG022A | X | 831699.80 | 26728826.20 | 0 | LG Series Wells-Borings_1980-82 |
| LG027 | | 827263.00 | 26732993.00 | 7 | |
| LG028A | | 827289.20 | 26733010.40 | 0 | |
| LG029 | | 823515.00 | 26735375.00 | 58 | |
| LG030 | | 823515.00 | 26735375.00 | 0 | |
| LG049 | | 835867.19 | 26734744.73 | No MCf | |
| LG055 | | 835838.54 | 26734924.42 | No MCf | |
| LG180 | | 836827.50 | 26728213.70 | No Data | |
| LG231 | X | 837411.60 | 26728199.40 | 75 | LG Series Wells-Borings_1980-82 |
| LG232 | X | 837354.50 | 26728203.20 | 275 | LG Series Wells-Borings_1980-82 |
| LG235 | X | 835955.73 | 26734661.40 | 84 | LG235-LG237.pdf |
| LG236 | X | 835937.50 | 26734856.71 | 64 | LG235-LG237.pdf |
| LK1 | | 827207.32 | 26727861.48 | 17 | |
| LK2 | | 827202.42 | 26727868.95 | 17.5 | |
| LK3 | | 827212.03 | 26727869.98 | 9 | |
| LK4 | | 827216.11 | 26727862.54 | 21.5 | |
| LK5 | | 827400.55 | 26727856.84 | 14 | |
| LK6 | | 827410.32 | 26727847.62 | 19 | |
| LNDMW1 | | 841144.00 | 26736147.00 | No Data | |
| LNDMW2 | | 840855.00 | 26737126.00 | No Data | |
| M-112 | X | 0.00 | 0.00 | 7.5 | KMG M Series Wells-Borings_1981-2002 |
| M-113 | X | 0.00 | 0.00 | 6 | KMG M Series Wells-Borings_1981-2002 |
| M-114 | X | 0.00 | 0.00 | 14 | KMG M Series Wells-Borings_1981-2002 |
| M-41 | X | 0.00 | 0.00 | 12 | KMG M Series Wells-Borings_1981-2002 |
| M-42 | X | 0.00 | 0.00 | 9 | KMG M Series Wells-Borings_1981-2002 |
| M-43 | X | 0.00 | 0.00 | 10.5 | KMG M Series Wells-Borings_1981-2002 |
| M-45 | X | 0.00 | 0.00 | 12.5 | KMG M Series Wells-Borings_1981-2002 |
| M-51 | X | 0.00 | 0.00 | 1 | KMG M Series Wells-Borings_1981-2002 |
| MCF-05 | X | 832871.21 | 26728512.84 | 193.4 | BRC Dataset_27_MCF_BoringLogs |
| MCF-06A | X | 834909.22 | 26729273.85 | 349 | BRC Dataset_27_MCF_BoringLogs |
| MCF-06A-R | | 834925.18 | 26729029.99 | 322 | |
| MCF-06B | X | 834930.92 | 26729012.42 | 42.23 | BRC Dataset_27_MCF_BoringLogs |
| MCF-06C | X | 834945.84 | 26729004.59 | 19.42 | BRC Dataset_27_MCF_BoringLogs |
| MCF-07 | X | 837113.60 | 26729569.85 | 171 | BRC Dataset_27_MCF_BoringLogs |
| MCF-08A | X | 827753.96 | 26733221.86 | 303.5 | BRC Dataset_27_MCF_BoringLogs |
| MCF-08B | X | 827771.70 | 26733214.25 | 86.3 | BRC Dataset_27_MCF_BoringLogs |
| MCF-08B-R | | 827781.62 | 26733205.95 | 101 | |
| MCF-10A | X | 825973.72 | 26730015.36 | 339.2 | BRC Dataset_27_MCF_BoringLogs |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| MCF-10B | X | 825951.40 | 26730022.81 | 63.81 | BRC Dataset_27_MCF_BoringLogs |
| MCF-12A | X | 840058.76 | 26727429.27 | 32.82 | BRC Dataset_27_MCF_BoringLogs |
| MCF-12B | X | 840046.01 | 26727441.77 | 125.94 | BRC Dataset_27_MCF_BoringLogs |
| MCF-12C | X | 840042.06 | 26727428.91 | 319.7 | BRC Dataset_27_MCF_BoringLogs |
| MCF-17A | | 825853.00 | 26732675.00 | 346 | |
| MCF-18A | | 831874.00 | 26731588.00 | 381.5 | |
| MCF-19A | | 830525.00 | 26728055.00 | 368.5 | |
| MCF-20A | | 833377.00 | 26728861.00 | 364.5 | |
| MCF-21A | | 838100.00 | 26727963.00 | 345 | |
| MCF-22A | | 840735.00 | 26729054.00 | 320 | |
| MCF-23 | X | 834539.51 | 26732404.95 | No MCf | BRC Dataset_27_MCF_BoringLogs |
| MCF-28A | | 830679.60 | 26732313.65 | 353 | |
| MCF-28B | | 830661.57 | 26732313.02 | 353 | |
| MCF-29A | | 833957.87 | 26733436.56 | 318 | |
| MCF-29B | | 833954.70 | 26733444.92 | 318 | |
| MCF-30A | | 836135.15 | 26733724.11 | 338 | |
| MCF-30B | | 836130.63 | 26733707.02 | 338 | |
| MCF-31A | | 838327.15 | 26733550.26 | 356.5 | |
| MCF-31B | | 838313.96 | 26733552.24 | 356.5 | |
| MP-2 | | 826366.60 | 26733282.30 | 2 | |
| MP-3 | | 826420.00 | 26733282.50 | -2 | |
| MP-4 | | 826471.90 | 26733283.40 | 5.5 | |
| MP-5 | | 826534.10 | 26733283.50 | 7 | |
| MP-7 | | 826392.70 | 26733282.50 | 5.5 | |
| MP-8 | | 826443.90 | 26733282.00 | 8.5 | |
| MW-01 | X | 839445.13 | 26734848.86 | -1.55 | CoHend Landfill Wells-Borings_1998.pdf |
| MW-02 | | 838994.31 | 26734479.04 | 38 | |
| MW-03 | X | 840598.27 | 26735455.24 | 20 | CoHend Landfill Wells-Borings_1998.pdf |
| MW-04 | X | 838288.59 | 26733552.56 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-05 | X | 840501.59 | 26733563.59 | 31.7 | CoHend Landfill Wells-Borings_1998.pdf |
| MW-06 | X | 841529.77 | 26733597.06 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-07 | X | 841228.14 | 26735162.90 | No Data | CoHend Landfill Wells-Borings_1998.pdf |
| MW-08 | X | 841021.90 | 26734440.76 | No Data | CoHend Landfill Wells-Borings_1998.pdf |
| MW-09 | X | 841337.98 | 26735550.28 | No Data | CoHend Landfill Wells-Borings_1998.pdf |
| MW-10 | X | 840223.39 | 26734020.28 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-11 | X | 839738.69 | 26733930.73 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-12 | X | 838999.95 | 26733801.37 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-13 | X | 838307.02 | 26734741.23 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-14 | X | 838958.27 | 26735168.91 | No MCf | CoHend Landfill Wells-Borings_1998.pdf |
| MW-AA | X | 822059.00 | 26729177.00 | 9.5 | 1997 & 1998.pdf |
| MW-K2 | X | 828540.82 | 26727994.83 | 10 | 1997 & 1998.pdf |
| MW-K4 | X | 828994.00 | 26728410.00 | 15 | 1997 & 1998.pdf |
| MW-K5 | X | 829617.00 | 26730252.00 | 31 | 1997 & 1998.pdf |
| MW-K6 | X | 830372.00 | 26733255.00 | 38 | 1997 & 1998.pdf |
| MW-K7 | X | 831682.00 | 26733239.00 | No MCf | 1997 & 1998.pdf |
| MW-K8 | X | 832265.00 | 26733083.00 | No MCf | 1997 & 1998.pdf |
| MW-N | X | 823649.00 | 26727964.00 | 13 | 1997 & 1998.pdf |
| MW-O | X | 824197.00 | 26727965.00 | 13 | 1997 & 1998.pdf |
| MW-P | X | 824773.00 | 26727968.00 | 10.5 | 1997 & 1998.pdf |
| MW-QD | X | 826074.00 | 26727995.00 | 36 | 1997 & 1998.pdf |
| MW-QS | X | 826074.00 | 26727995.00 | 7 | 1997 & 1998.pdf |
| MW-S | X | 826941.00 | 26730853.00 | 14 | 1997 & 1998.pdf |
| MW-T | X | 826644.00 | 26732347.00 | 27 | 1997 & 1998.pdf |
| MW-U | X | 826312.00 | 26733219.00 | 23 | 1997 & 1998.pdf |
| MW-V | X | 825243.00 | 26733189.00 | 23 | 1997 & 1998.pdf |
| NRMMW-1 | | 835217.20 | 26730338.32 | No Data | |
| NRMMW-2 | | 834326.54 | 26731440.61 | No Data | |
| NRMMW-3 | | 834194.04 | 26729352.57 | No Data | |
| NX-17 | | 823645.90 | 26727961.68 | 26 | |
| NXP-18 | X | 823623.69 | 26727952.96 | 0 | 2004.pdf |
| NY-15 | X | 823414.10 | 26727670.20 | 9 | 2004.pdf |
| OX-16 | X | 824203.08 | 26727965.13 | 26.5 | 2004.pdf |
| OXO-16 | | 824232.80 | 26727992.51 | 3.5 | |
| OXP-16 | | 824232.15 | 26727965.41 | 4.5 | |
| OY-8 | X | 824123.60 | 26728244.00 | 8.5 | 2004.pdf |
| PB-104 | | 832611.93 | 26733397.39 | 0.5 | |
| PC-1 | X | 830925.11 | 26730308.65 | 1 | Kerr McGee.pdf |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| PC-2 | X | 830443.45 | 26730209.58 | 4 | Kerr McGee.pdf |
| PC-3 | X | 830727.23 | 26730271.96 | 1 | Kerr McGee.pdf |
| PC-4 | X | 831171.80 | 26730353.42 | 1.5 | Kerr McGee.pdf |
| PC-5 | X | 830583.32 | 26730236.33 | 1 | Kerr McGee.pdf |
| PC-6 | X | 831073.26 | 26730334.85 | 2 | Kerr McGee.pdf |
| PC-7 | X | 831271.36 | 26730372.48 | 3 | Kerr McGee.pdf |
| PC-8 | X | 831129.42 | 26730316.40 | 1 | Kerr McGee.pdf |
| PC-9 | X | 830329.04 | 26727966.33 | 1 | Kerr McGee.pdf |
| PC-10 | X | 829891.09 | 26727968.38 | 0.5 | Kerr McGee.pdf |
| PC-11 | X | 829541.61 | 26727965.78 | 0.5 | Kerr McGee.pdf |
| PC-12 | X | 829430.43 | 26728102.92 | 1.5 | Kerr McGee.pdf |
| PC-13 | X | 829144.77 | 26728097.93 | 1.5 | Kerr McGee.pdf |
| PC-14 | X | 829037.20 | 26728095.97 | 1 | Kerr McGee.pdf |
| PC-15 | X | 828936.84 | 26728094.18 | 1 | Kerr McGee.pdf |
| PC-16 | X | 828837.46 | 26728091.03 | 1 | Kerr McGee.pdf |
| PC-17 | X | 828732.63 | 26728089.23 | 7 | Kerr McGee.pdf |
| PC-18 | X | 828636.25 | 26728079.97 | 1 | Kerr McGee.pdf |
| PC-19 | X | 828510.28 | 26728053.19 | 4 | Kerr McGee.pdf |
| PC-20 | X | 828413.12 | 26728053.07 | 2 | Kerr McGee.pdf |
| PC-43 | X | 823403.61 | 26727715.42 | 0.01 | Kerr McGee.pdf |
| PC-52 | X | 830190.60 | 26730231.27 | 1 | Kerr McGee.pdf |
| PC-53 | X | 829941.58 | 26730225.29 | 3 | Kerr McGee.pdf |
| PC-55 | X | 828530.49 | 26728056.66 | No MCf | Kerr McGee.pdf |
| PC-56 | X | 830645.29 | 26732289.43 | 6 | Kerr McGee.pdf |
| PC-57 | X | 830831.27 | 26732239.50 | 3 | Kerr McGee.pdf |
| PC-58 | X | 831123.78 | 26732118.20 | 4.5 | Kerr McGee.pdf |
| PC-59 | X | 830150.30 | 26732452.69 | 6 | Kerr McGee.pdf |
| PC-60 | X | 830405.14 | 26732358.75 | 4 | Kerr McGee.pdf |
| PC-61 | X | 830524.66 | 26732323.18 | 3 | Kerr McGee.pdf |
| PC-62 | X | 829764.28 | 26732733.52 | 3 | Kerr McGee.pdf |
| PC-63 | X | 829925.71 | 26732553.25 | 2 | Kerr McGee.pdf |
| PC-68 | X | 829616.96 | 26732906.82 | 5.3 | Kerr McGee.pdf |
| PC-69 | X | 829478.05 | 26733074.08 | 2 | Kerr McGee.pdf |
| PC-70 | X | 828700.19 | 26728084.94 | 0 | Kerr McGee.pdf |
| PC-74 | X | 829203.52 | 26734003.52 | 14 | Kerr McGee.pdf |
| PC-75 | X | 829194.53 | 26734004.98 | | Kerr McGee.pdf |
| PC-76 | X | 829183.79 | 26734006.74 | No MCf | Kerr McGee.pdf |
| PC-77 | X | 829031.63 | 26733568.07 | No MCf | Kerr McGee.pdf |
| PC-78 | X | 829033.25 | 26733560.32 | No MCf | Kerr McGee.pdf |
| PC-79 | X | 829815.15 | 26733246.70 | 28 | Kerr McGee.pdf |
| PC-80 | X | 829823.82 | 26733250.46 | No MCf | Kerr McGee.pdf |
| PC-81 | X | 829833.40 | 26733254.77 | No MCf | Kerr McGee.pdf |
| PC-82 | X | 830316.93 | 26733194.96 | 11 | Kerr McGee.pdf |
| PC-83 | X | 830325.43 | 26733201.37 | No MCf | Kerr McGee.pdf |
| PC-84 | X | 830332.58 | 26733208.53 | | Kerr McGee.pdf |
| PC-85 | X | 830816.05 | 26733185.56 | 20 | Kerr McGee.pdf |
| PC-86 | X | 830826.99 | 26733185.76 | No MCf | Kerr McGee.pdf |
| PC-87 | X | 830837.82 | 26733185.37 | No MCf | Kerr McGee.pdf |
| PC-88 | X | 831259.41 | 26733178.42 | 11 | Kerr McGee.pdf |
| PC-89 | X | 831264.70 | 26733184.33 | | Kerr McGee.pdf |
| PC-90 | X | 831271.92 | 26733192.63 | No MCf | Kerr McGee.pdf |
| PC-91 | X | 831729.99 | 26733110.85 | 25 | Kerr McGee.pdf |
| PC-92 | X | 831749.30 | 26733109.85 | No MCf | Kerr McGee.pdf |
| PC-93 | X | 832179.60 | 26733117.81 | 17 | Kerr McGee.pdf |
| PC-94 | X | 832189.05 | 26733122.48 | No MCf | Kerr McGee.pdf |
| PC-95 | X | 831227.21 | 26733449.91 | 7 | Kerr McGee.pdf |
| PC-96 | X | 830896.56 | 26733450.83 | 3 | Kerr McGee.pdf |
| PC-97 | X | 831565.69 | 26733441.54 | 2 | Kerr McGee.pdf |
| PC-98 | X | 829519.86 | 26730256.09 | 4 | Kerr McGee.pdf |
| PC-98R | X | 829522.58 | 26730260.53 | 1 | Kerr McGee.pdf |
| PC-99 | X | 831242.35 | 26733140.18 | No MCf | Kerr McGee.pdf |
| PC-99R | X | 831244.93 | 26733143.32 | 2 | Kerr McGee.pdf |
| PC-99R2 | X | 831258.73 | 26733155.42 | 3.3 | KMG PC Series Wells-Borings_1998-2003 |
| PC-99R3 | X | 831255.55 | 26733160.44 | 6 | KMG PC Series Wells-Borings_1998-2003 |
| PC-100 | X | 829544.65 | 26730298.84 | -0.03 | Kerr McGee.pdf |
| PC-100R | X | 829542.48 | 26730295.31 | 1 | Kerr McGee.pdf |
| PC-101 | X | 828714.91 | 26728110.94 | 2 | Kerr McGee.pdf |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| PC-101R | X | 828711.72 | 26728107.74 | 0.5 | Kerr McGee.pdf |
| PC-102 | X | 831259.54 | 26733174.53 | No MCf | Kerr McGee.pdf |
| PC-103 | X | 829110.87 | 26730205.73 | 1 | Kerr McGee.pdf |
| PC-104 | X | 829277.08 | 26731049.70 | 1 | Kerr McGee.pdf |
| PC-105 | X | 828827.49 | 26731425.85 | 14 | Kerr McGee.pdf |
| PC-106 | X | 827110.06 | 26730247.51 | 7 | Kerr McGee.pdf |
| PC-107 | X | 827136.50 | 26729287.58 | 4 | Kerr McGee.pdf |
| PC-108 | X | 828526.96 | 26731913.05 | 10 | Kerr McGee.pdf |
| PC-109 | X | 828117.18 | 26732063.87 | 15 | Kerr McGee.pdf |
| PC-110 | X | 826778.31 | 26731928.11 | No MCf | Kerr McGee.pdf |
| PC-111 | X | 826540.15 | 26732782.13 | 25 | Kerr McGee.pdf |
| PC-112 | X | 828898.31 | 26732800.69 | 4 | Kerr McGee.pdf |
| PC-113 | X | 829176.92 | 26732302.72 | 24 | Kerr McGee.pdf |
| PC-114 | X | 829700.65 | 26732303.16 | 6 | Kerr McGee.pdf |
| PC-115 | X | 831044.52 | 26733155.24 | 6.3 | KMG PC Series Wells-Borings_1998-2003 |
| PC-115R | X | 831148.64 | 26733131.33 | 8 | KMG PC Series Wells-Borings_1998-2003 |
| PC-116 | X | 831364.81 | 26733213.14 | 8 | KMG PC Series Wells-Borings_1998-2003 |
| PC-116R | X | 831348.43 | 26733203.15 | 9 | KMG PC Series Wells-Borings_1998-2003 |
| PC-117 | X | 831422.37 | 26733275.94 | 6.5 | KMG PC Series Wells-Borings_1998-2003 |
| PC-118 | X | 831051.99 | 26733167.39 | 2.5 | KMG PC Series Wells-Borings_1998-2003 |
| PC-119 | X | 830951.29 | 26733188.50 | 2 | KMG PC Series Wells-Borings_1998-2003 |
| PC-120 | X | 830851.47 | 26733185.77 | 3 | KMCC Boring Logs.pdf |
| PC-121 | X | 830751.31 | 26733180.39 | No MCf | KMG PC Series Wells-Borings_1998-2003 |
| PC-122 | X | 829675.17 | 26728145.17 | 3 | Kerr McGee.pdf |
| PC-133 | | 831758.00 | 26733209.00 | 2.2 | |
| PC-134 | X | 828776.17 | 26728126.42 | 21 | ENSR-AECOM capturezonewells |
| PC-134A | X | 828775.80 | 26728143.15 | 21 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-135 | X | 828765.25 | 26728123.18 | 2 | ENSR-AECOM capturezonewells |
| PC-135A | X | 828767.49 | 26728143.03 | 4 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-136 | X | 829517.89 | 26728191.37 | 1 | ENSR-AECOM capturezonewells |
| PC-137 | X | 829517.57 | 26728198.98 | 34.0175 | ENSR-AECOM capturezonewells |
| PC-141 | X | 828446.31 | 26728106.63 | 23 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-142 | X | 828436.04 | 26728106.76 | No MCf | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-143 | X | 828698.71 | 26728238.64 | 35 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-144 | X | 828903.75 | 26728223.86 | 7.5 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-145 | X | 829536.07 | 26728324.97 | 5 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-146 | X | 829812.54 | 26728152.19 | 5 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-147 | X | 829767.43 | 26728153.17 | 3 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-148 | X | 829249.33 | 26728124.42 | 25 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-149 | X | 829117.97 | 26728122.90 | 18 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PC-150 | X | 828915.29 | 26728104.18 | 6 | Field Logs ARP-3A, ART-7B, I-AC, I-AD, M-48A, PC-134A, 135A, PC-141-150 |
| PG109 | X | 824917.00 | 26727734.20 | 5 | PG Series Wells-Borings_1980-82 |
| PG110 | X | 826385.10 | 26727910.70 | 2 | PG Series Wells-Borings_1980-82 |
| PG111 | X | 827744.40 | 26728073.60 | 0 | PG Series Wells-Borings_1980-82 |
| PG112 | X | 829099.40 | 26728240.60 | 0 | PG Series Wells-Borings_1980-82 |
| PG212 | | 830103.12 | 26727908.49 | 14 | |
| PG213 | | 830133.77 | 26728100.65 | 0.5 | |
| PG214 | X | 830651.71 | 26727983.15 | 0 | PG Series Wells-Borings_1980-82 |
| PG215 | X | 831127.48 | 26728153.67 | 0 | PG Series Wells-Borings_1980-82 |
| PG216 | | 832683.15 | 26733004.06 | 4.7 | |
| PG217A | | 834363.80 | 26732525.30 | 3.4 | |
| PG223 | | 826731.40 | 26730875.40 | 0.2 | |
| PG224 | | 828737.26 | 26730195.68 | 0.4 | |
| PG225 | | 831419.05 | 26730393.23 | 6 | |
| PG226 | | 828896.94 | 26731764.83 | 4.9 | |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| PG227 | | 830398.98 | 26731371.62 | 4 | |
| PG228 | | 830802.10 | 26731367.60 | 10 | |
| PG229 | | 830459.01 | 26732377.64 | 1 | |
| PG230 | | 828400.47 | 26732829.07 | 6 | |
| PG231 | X | 832628.40 | 26728945.20 | 1.4 | PG Series Wells-Borings_1980-82 |
| PG232 | X | 833251.40 | 26729006.70 | 1.4 | PG Series Wells-Borings_1980-82 |
| PG233 | X | 833861.30 | 26728966.10 | 5 | PG Series Wells-Borings_1980-82 |
| PG234 | | 834960.18 | 26732021.69 | 11 | |
| PG250 | | 831006.29 | 26728837.41 | No MCf | |
| PG251 | | 829169.60 | 26729060.20 | No Data | |
| PG252 | | 829739.30 | 26729981.40 | No MCf | |
| PG253 | | 831977.53 | 26731714.29 | 0 | |
| PG256 | | 832117.78 | 26732045.40 | 5 | |
| PL-635 | | 0.00 | 0.00 | No Data | |
| PL-637 | | 0.00 | 0.00 | No Data | |
| PMW-1 | X | 826468.90 | 26733318.20 | 8 | PMW-1.pdf |
| PMW-2 | | 826596.00 | 26733317.72 | 12 | |
| PMW-3 | | 826688.80 | 26733346.40 | 9 | |
| PMW-4 | | 826635.40 | 26733437.00 | 11.5 | |
| PMW-5 | | 826814.80 | 26733442.70 | 12 | |
| PMW-6 | | 826821.60 | 26733562.00 | 10.5 | |
| PMW-7 | | 826962.14 | 26733788.63 | 11 | |
| PMW-8 | | 827253.81 | 26733988.97 | 8.5 | |
| PSW-1 | | 827936.40 | 26727701.10 | 0 | |
| PSW-2 | | 827915.30 | 26727700.60 | 0 | |
| PSW-3 | | 827936.40 | 26727680.00 | 0 | |
| PSW-4 | | 827915.30 | 26727679.50 | 0 | |
| PSW-5 | | 827936.90 | 26727657.00 | 0 | |
| PSW-6 | | 827915.30 | 26727657.00 | 3 | |
| PSW-7 | | 827957.40 | 26727700.60 | No Data | |
| PW | | 825158.71 | 26728614.03 | 43 | |
| PWX-1 | | 826418.00 | 26733287.10 | 2.8 | |
| PWX-10 | | 826467.36 | 26733438.63 | 14.5 | |
| PWX-11 | | 826555.04 | 26733441.51 | 20.5 | |
| PWX-12 | | 826623.97 | 26733587.38 | 7 | |
| PWX-13 | | 826716.85 | 26733550.93 | 5 | |
| PWX-2 | | 826418.20 | 26733297.40 | 1.5 | |
| PWX-2 | | 826418.20 | 26733297.40 | 1.5 | |
| PWX-3 | | 826416.25 | 26733317.44 | 6 | |
| PWX-4 | | 826390.21 | 26733317.56 | 7.3 | |
| PWX-5 | | 826443.31 | 26733317.85 | 4 | |
| PWX-6 | | 826501.79 | 26733318.72 | 11.5 | |
| PWX-7 | | 826414.94 | 26733377.91 | 7.5 | |
| PWX-8 | | 826467.83 | 26733378.19 | 9 | |
| PWX-9 | | 826561.35 | 26733379.16 | 9 | |
| PX-15 | X | 824769.31 | 26727968.37 | 15.5 | 2004.pdf |
| PX-40 | X | 824778.75 | 26727968.46 | 34 | 2004.pdf |
| PXP-16 | | 824795.81 | 26727968.01 | 2.5 | |
| PY-14 | | 825017.12 | 26727951.78 | 10.5 | |
| PZ-13 | | 825169.90 | 26727954.00 | 12.3 | |
| RB-10 | | 839810.60 | 26731805.30 | 0 | |
| RB-11 | | 838644.60 | 26729824.10 | 0 | |
| RB-12 | | 838378.30 | 26730946.70 | 15 | |
| RB-13 | | 837235.00 | 26729634.40 | No MCf | |
| RB-14 | | 836915.40 | 26731526.20 | 0 | |
| RB-15 | | 836792.90 | 26733287.30 | 0 | |
| RB-16 | | 835966.20 | 26729404.60 | 0 | |
| RB-17 | | 836014.10 | 26732142.90 | 15 | |
| RB-18 | | 836202.60 | 26733459.90 | 6 | |
| RB-9 | | 840650.70 | 26730178.20 | 0 | |
| RIT-04 | | 827202.85 | 26733337.57 | 8.7 | |
| RIT-05 | | 827277.02 | 26733325.62 | 7.4 | |
| RIT-06 | | 827297.23 | 26733433.85 | 8.5 | |
| RIT-07 | | 826964.16 | 26733478.96 | 10.3 | |
| RIT-08 | | 827127.94 | 26733558.18 | 8.2 | |
| RIT-09 | | 826985.13 | 26733414.54 | 10.2 | |
| RIT-10 | | 827280.22 | 26733679.40 | 13 | |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| RIW-1 | | 826312.40 | 26733278.20 | 6 | |
| RIW-2 | | 826364.50 | 26733277.70 | 11.5 | |
| RIW-3 | | 826417.90 | 26733278.20 | 7 | |
| RIW-4 | | 826469.20 | 26733278.90 | 18 | |
| RIW-5 | | 826531.40 | 26733279.30 | 15.5 | |
| RIW-5A | | 826541.40 | 26733275.30 | 8 | |
| RIW-6 | | 826575.20 | 26733278.20 | 3.5 | |
| RIW-7 | | 826390.20 | 26733278.40 | 17.5 | |
| RIW-8 | | 826442.10 | 26733277.80 | 11 | |
| RMW-1 | | 836590.90 | 26733349.00 | No MCf | |
| RMW-10 | | 838327.30 | 26732382.80 | 55 | |
| RMW-2 | | 837630.00 | 26733266.70 | -5 | |
| RMW-3 | | 836157.80 | 26729506.90 | 27 | |
| RMW-4 | | 837713.40 | 26730309.60 | 45 | |
| RMW-5 | | 840409.40 | 26731274.00 | 0 | |
| RMW-6 | | 836946.90 | 26731386.60 | 14 | |
| RMW-7 | | 839535.20 | 26732460.00 | 26.5 | |
| RMW-8 | | 835939.60 | 26731509.50 | No MCf | |
| RMW-9 | | 839611.60 | 26729845.70 | 35 | |
| RPZ-3 | | 839562.00 | 26730229.50 | 35 | |
| RPZ-4 | | 839114.90 | 26731546.00 | 35 | |
| RPZ-5 | | 836848.00 | 26732412.30 | -10 | |
| RRMW-1 | | 834195.26 | 26729352.68 | No Data | |
| SB-1-8 | X | 824928.20 | 26731968.90 | 30 | Book 2_2004.pdf |
| SB-2-7 | X | 824742.70 | 26731972.20 | 47.3 | Book 2_2004.pdf |
| SB-29-3 | X | 825052.30 | 26731965.60 | 11.3 | Book 2_2004.pdf |
| SB-3-13 | X | 824433.70 | 26731978.50 | 62.4 | Book 2_2004.pdf |
| SB-5-5 | X | 823505.90 | 26731993.00 | 37.5 | Book 2_2004.pdf |
| SB-5-6 | X | 822827.90 | 26731997.40 | 31.7 | KMG SB Series Wells-Borings_1999 |
| SBMW-11-11 | X | 824459.80 | 26732893.90 | 44.8 | Book 2_2004.pdf |
| SBMW-18-5 | X | 824190.70 | 26732562.50 | 40 | Book 2_2004.pdf |
| SBMW-4-4 | X | 823397.50 | 26732849.20 | 21 | Book 2_2004.pdf |
| SBMW-6-12 | X | 823897.80 | 26732861.90 | 25 | Book 2_2004.pdf |
| SBO-1A-3 | X | 824933.80 | 26731977.10 | 5 | Book 2_2004.pdf |
| SBO-1B-2 | X | 824942.10 | 26731989.60 | 8.5 | Book 2_2004.pdf |
| SBO-29-4 | X | 825058.70 | 26731973.80 | 5 | Book 2_2004.pdf |
| SBO-2A-7 | X | 824749.40 | 26731978.70 | 5 | Book 2_2004.pdf |
| SBO-2B-7 | | 824760.40 | 26731990.50 | 6.5 | |
| TWE-107 | X | 826427.80 | 26727636.60 | 186.5 | 2003_TWA.pdf |
| TWE-15 | X | 826426.20 | 26727676.60 | 9 | 2003_TWA.pdf |
| TWE-18 | X | 826426.70 | 26727666.40 | 20 | 2003_TWA.pdf |
| TWE-33 | X | 826427.00 | 26727656.30 | 36.2 | 2003_TWA.pdf |
| TWE-51 | | 826427.00 | 26727646.50 | 50.5 | |
| TWF | | 825345.24 | 26727954.86 | 21 | |
| TWH-14 | | 825097.20 | 26727472.80 | 20.5 | |
| TWJ | | 825255.09 | 26727953.95 | 11 | |
| UA | | 825805.37 | 26733225.58 | 18 | |
| UB | | 826055.83 | 26733256.12 | 12 | |
| UB2 | | 826177.49 | 26733243.68 | 11 | |
| UB3 | | 826244.83 | 26733240.59 | 8 | |
| UB4-15 | | 826282.10 | 26733244.00 | 11 | |
| UB5 | | 826427.72 | 26733248.16 | No MCf | |
| UC-1 | | 825882.70 | 26733747.80 | 40.2 | |
| UC-3 | | 826729.20 | 26733740.60 | 26 | |
| UC-4 | | 827027.30 | 26733933.70 | 15.8 | |
| UD-2 | | 826218.40 | 26733561.40 | 20 | |
| USGS-SE | | 835611.58 | 26738794.90 | No MCf | |
| UWO-16 | X | 826575.50 | 26733241.60 | 22.5 | Book 2_2004.pdf |
| UXO-16 | X | 826778.31 | 26733263.60 | 18 | Book 2_2004.pdf |
| UYO-16 | X | 827047.00 | 26733277.70 | 19 | Book 2_2004.pdf |
| UYP-11 | X | 827029.80 | 26733252.70 | 6 | Book 2_2004.pdf |
| UZO-17 | X | 827323.40 | 26733274.00 | 16 | Book 2_2004.pdf |
| W02 | | 837329.05 | 26734843.68 | No Data | |
| W03 | | 834580.13 | 26733881.37 | No Data | |
| W04 | | 832197.49 | 26733133.55 | No Data | |
| WMW3.5N | | 844264.27 | 26737807.27 | No Data | |
| WMW3.5S | | 844716.43 | 26737315.11 | No Data | |

| Well ID | Copy of Boring Log Available | Easting | Northing | Thickness of MCf (feet) | Boring Log File Name |
|---|---|---|---|---|---|
| WMW4.9N | | 838409.20 | 26736763.80 | No Data | |
| WMW4.9S | | 838417.15 | 26735283.89 | No Data | |
| WMW5.58S | X | 835071.22 | 26734663.59 | No Data | SNWA LVW Logs 2002 |
| WMW5.58SD | | 835091.50 | 26734645.80 | No MCf | |
| WMW5.58SI | | 835065.43 | 26734651.40 | No MCf | |
| WMW5.58SS | | 835065.43 | 26734651.40 | No MCf | |
| WMW5.5S | | 835769.77 | 26733985.45 | No Data | |
| WMW5.7N | X | 834470.77 | 26734436.11 | No Data | SNWA LVW Logs 2002 |
| WMW5.85S | X | 833916.85 | 26734024.21 | No Data | SNWA LVW Logs 2002 |
| WMW6.0N | | 833043.55 | 26734210.83 | No Data | |
| WMW6.0S | | 833065.78 | 26733934.90 | No Data | |
| WMW6.15N | | 832479.59 | 26735360.82 | No Data | |
| WMW6.15S | X | 832113.33 | 26734093.14 | No Data | SNWA LVW Logs 2002 |
| WMW6.2N | | 832107.00 | 26735130.00 | No Data | |
| WMW6.55S | | 830220.23 | 26734543.98 | No Data | |
| WMW7.8N | | 824426.00 | 26737604.00 | No Data | |
| WTPL | | 843711.38 | 26728008.00 | No Data | |
| WW-1 | | 825800.00 | 26727500.00 | 22 | |
| WW-10 | | 836483.66 | 26728801.46 | 139 | |
| WW-4 | | 837439.00 | 26735669.70 | 0 | |
| WW-5 | | 823079.16 | 26729883.49 | 66 | |
| WW-6 | X | 836483.66 | 26728801.46 | 139 | WTB Series Wells-Borings |
| 613 | 313 | Total Wells | | | |

Notes:
MCf - Muddy Creek formation.
-0.5 - Negative number is the result of data contained in the database provided (14.01.31 MASTER January 2014_All Wells DBase_edited Broadbent.xls) where total boring depth is shallower than top of MCf value entered.

# Appendix B

# GeoVision Technical Approach, SOPs and Quality Assurance Program

May 18, 2016

Proposal No. P15-0557C

Mr. Joe Harrigan
AECOM
1220 Avenida Acaso
Camarillo, California 93012

**TECHNICAL APPROACH & COST PROPOSAL**
**Geophysical Pilot Test**
**NERT Downgradient Study Area Henderson, Nevada**

Dear Mr. Harrigan:

**GEO***Vision* Geophysical Services is pleased to present this proposal to conduct a geophysical pilot test at the NERT Downgradient Study Area, Henderson Nevada. The geophysical pilot study will involve acquisition of time domain electromagnetic (TDEM), electrical resistivity imaging (ERI), seismic refraction (SR) and either multi-channel analysis of surface waves (MASW) or refraction mictrotremor (ReMi) data along two (2) 500 ft long profiles . Technical notes summarizing the proposed geophysical techniques are enclosed. The objectives of the pilot study are to assess the capability of the various geophysical techniques at mapping the depth of the Muddy Creek Formation (Tertiary Clay Unit), whereby geophysical surveys can be combined to map paleochannels cut into the clay unit.

The geophysical investigation will be managed by a California Professional Geophysicist and a California Professional Geophysicist will supervise all field activities.

## TECHNICAL APPROACH

The success of a surface geophysical investigation is a function of the degree of contrast in some physical property (e.g. density, electrical resistivity, dielectric permittivity, magnetic susceptibility, seismic velocity, etc.) between the target of interest and surrounding medium. Previous investigations in the site vicinity have generally revealed a strong contrast in the electrical resistivity between the high resistivity sands overlying the low resistivity clay unit. Therefore, electrical resistivity and electromagnetic methods likely have the greatest potential for mapping paleochannels cut into the clays unit. Both electrical resistivity and electromagnetic methods should be capable to mapping the top of the clay unit; however, only electromagnetic methods will be capable of imaging a significant depth into the clay unit. The electrical resistivity method will perform better than most electromagnetic methods if there are significant cultural features in close proximity to the site such as power lines, transmission towers, fences, pipelines. In the event of fence lines and pipelines, it will be crucial to orient the resistivity profiles perpendicular to the features. Seismic methods will only be applicable to site characterization if there is a significant contrast in seismic velocity between the near surface sand units and underlying clay units which is possible, but unlikely. The P-wave seismic refraction technique may be further limited by the presence of saturated sediments overlying the clay unit in which case only depth to groundwater can be determined.

In this proposal, we provide costs for acquiring electrical TDEM, ERI, seismic refraction, MASW and ReMi data along two (2) nominal 500 ft long pilot study profiles. We also provide optional costs to acquire controlled source audio electromagnetic (CSAMT) data along two profiles, either instead of or in addition to the TDEM data because the TDEM method may not be applicable to site wide investigation due to access limitations. A more detailed description of the proposed geophysical methodology and procedures follows.

***Time Domain Electromagnetic or Controlled Source Audio Electromagnetic Survey***

TDEM data will be acquired along two 500 ft profiles at the site in an attempt to map depth to the Muddy Creek Formation. TDEM soundings will be conducted at 100 ft intervals along each 500 ft profile for a total of 12 sounding locations.

A Geonics EM47 transmitter (Tx) and a PROTEM digital receiver (Rx), or equivalent, will be used for the TDEM soundings. The TDEM soundings will be conducted in the central-loop sounding mode where the receiver coil is placed in the center of the transmitter loop during data recording. The Geonics EM47 is capable of imaging electrical structure to a depth of about 100 ft using a 100 to 130 ft transmitter loop.

The transmitter loop will consist of insulated 8 gauge copper wire placed on the ground in a square loop with 100 to 150 ft sides. The EM47 transmitter is powered by internal batteries. The EM47 transmitter operates at three user-selectable repetition frequencies of 285, 75, and 30 Hz. A high frequency receiver coil, which is a multi-turn, air-cored coil with diameters of 1 m and bandwidth of 850 kHz, is used with the EM47 transmitter. A wood leveling frame or leveling legs are used to orient the receiver coil horizontally, thereby allowing the vertical component of the decaying secondary magnetic field to be recorded. A reference cable between the transmitter and receiver synchronizes the system. Measurements will be made at repetition rates of 285, 75, and 30 Hz with the EM47. Hundreds to thousands of measurements will be stacked at each location to improve the signal to noise ratio. The resulting data from each sounding will be stored in the internal memory of the receiver and periodically downloaded to a laptop computer.

TDEM sounding data will be processed using the one-dimensional forward and inverse modeling computer program TEMIX-GL by Interpex Ltd, or equivalent. The underlying assumptions in one-dimensional modeling programs are that subsurface geological layers are horizontal and that the resistivity of each layer is homogeneous and isotropic. Lateral variation of resistivity or dipping structures may, therefore, cause errors in the one-dimensional models. Data processing involves loading the field data into TEMIX-GL, entering header information and pertinent field parameters, masking noisy data values, performing forward modeling to establish a realistic starting resistivity versus depth model, and carrying out inverse modeling to find a model that most closely fits the data in a least squares sense. Equivalence analysis will be performed on the inverse models, to determine the range of models that fit the data nearly as well as the best-fit model (error no more than one percent higher than that of the best-fit model). For QC purposes, a TDEM sounding will be repeated at a single station location on one of the profiles.

Although the TDEM method has been successfully applied in the site vicinity on previous projects, it may not be applicable to this investigation because site access will be limited to narrow corridors without sufficient space to place transmitter loops. Therefore, we propose to optionally evaluate a CSAMT technique where the receivers can be placed along a single profile with the transmitter located along a parallel profile 750 to 1000 ft away. A Geometrics Stratagem EH4 electromagnetic system will be utilized for data acquisition. To evaluate the technique along the 500 ft pilot study profiles it will only be necessary to place the transmitter at one or two locations up to 1000 ft from the profile. Measurements will be made at 50 ft intervals along each profile. For QC purposes, two CASMT sounding locations will be repeated on one of the profiles.

***Electrical Resistivity Imaging***

ERI data will be collected along two pilot study profiles to evaluate the effectiveness of the technique at mapping the top of the Muddy Creek Formation.

The 2-D resistivity data will be acquired using an AGI Super Sting 56-electrode system. A 10 or 15 electrode spacing is proposed for a maximum line length of about 550 to 825 ft. 2-D resistivity data will be acquired using a minimum of three (3) array geometries (e.g. Wenner, Inverse Schlumberger, dipole-dipole, strong gradient) to determine the most effective geometry for site conditions. Relative elevations of the electrode locations will be measured with total station system or level. Once the line is laid out the resistivity unit will be programmed to automatically acquire and store field measurements. A 2-D inversion of the field data will be conducted using the computer software package EarthImager, RES2DINV, or equivalent. The result of the data inversion will be a 2-D model of resistivity versus depth along each profile. For QC purposes, resistivity data acquisition will be repeated with one array geometry on one of the profiles.

***P-Wave Seismic Refraction and Active/Passive Surface Wave Survey***

P-wave seismic refraction, MASW and ReMi data will be acquired along two pilot study profiles to determine if there is a significant P- or S-wave velocity contrast between the Muddy Creek Formation and overlying sediments.

The seismograph used during this investigation will consist of a Geometrics Geode signal enhancement seismograph with 48 channels. The P-wave seismic source will consist of an accelerated weight drop (AWD), which will require vehicle access along the profile. Receivers will consist of 4.5-Hz vertical geophones, which are required for surface wave data acquisition. The seismic line will consist of a single spread of 48 geophones spaced 10 to 12.5 ft apart for a spread length of 470 to 587.5 ft. A minimum of eleven (11) shot points will be occupied per spread (end shots, shot points at six geophone intervals and off-end shots, as possible). Seismic data will be stored on the seismograph's hard disk or laptop computer. Relative elevations along each seismic line will be measured with an engineer's transit and rod or total station system. The ends of each seismic line will be surveyed with a GPS system to tie the survey to the State Plane Coordinate System. The seismic refraction data will be modeled using the generalized reciprocal method (GRM) or a tomographic inversion routine. For QC purposes, two shot locations will be repeated on one of the profiles and a direct comparison of waveforms made.

A minimum of 15 minutes of ambient noise data will be recorded into the seismic refraction array and data processed using the extended spatial correlation and/or ReMi™ techniques. Passive surface wave data acquired using 2-D arrays (e.g. triangular, circular, L-shaped) are much more reliable than linear arrays but are not applicable to this investigation due to expected site access restrictions and, therefore, will not be evaluated.

MASW data is best acquired using a smaller geophone spacing than utilized for seismic refraction acquisition and, therefore, it is not practical to acquire the two datasets simultaneously. Additionally, for evaluation purposes it is best to first conduct a 1-D sounding using the MASW technique rather than 2-D imaging. When acquiring 2-D MASW data, a single source location is occupied at each measurement location than then the active receiver array and source location are moved along the array. Such a field approach for a feasibility study does not yield enough data to optimize survey design. We, therefore, propose to acquire a 1-D MASW data set beneath a 235 ft segment of each pilot study line using a 48 channel array with 5 ft geophone spacing and a minimum of 9 source locations (4 source locations offset from each end of the array) and a source location in the center of the array. The AWD will be used as the energy source for the off- end shot locations and multiple hammer sources (3 and 10 or 20 lb sledgehammer) will be used at the near offset and center shot locations. GEOVision maintains about 10 different commercial and in-house software packages for active and passive surface wave imaging which will be used for data reduction and modeling, as appropriate. For QC purposes, two shot locations will be repeated on one of the profiles and a direct comparison of surface wave dispersion data made.

## REPORT

Prior to the field investigation a work plan will developed, which will include Standard Operating Procedures (SOP) and our Quality Assurance Program. ASTM Standard may be utilized in lieu of an SOP, as appropriate. Upon competition of the geophysical survey, a data report will be developed and will include a discussion of results and recommendations regarding the applicability of the various methods. The report will also include a site map showing the location of the geophysical traverses/stations, interpreted geophysical data sections and field notes from the geophysical investigation. The report will be reviewed and approved by a California Professional Geophysicist.

## SCHEDULE

We can begin this investigation within three weeks of receiving notice to proceed. The duration of the proposed field program will be about one week. The final report will be delivered within three weeks of completing fieldwork or within one week of receiving survey data for the lines, whichever is later.

## COST

Costs for the geophysical investigation are summarized in the attached Table 1. Backup data for the cost estimates are provided as Tables 2 to 10.

## TERMS

We require a written purchase order before mobilization. Terms and Conditions will be under an MSA executed between GEOVision and AECOM.

Please do not hesitate to contact me at (951) 549-1234 or by email at amartin@geovision.com should you have any questions regarding this proposal or require additional information.

We look forward to working with you on this project.

Yours truly,
**GEO***Vision* Geophysical Services

Antony J. Martin, P.GP.
Technical Director

Attachments:

Tables 1 to 10
Technical Note – Seismic Refraction Method
Technical Note – Active and Passive Surface Waves Method
Technical Note – Electrical Resistivity Method
Technical Note – TDEM Method

# PROCEDURE FOR

# SEISMIC REFRACTION METHOD

**Reviewed 11/07/11**

## Background

This procedure describes a method for measuring shear and compressional wave velocities in soil and rock. The Seismic Refraction Method is applied by generating compressional waves (*P*) (and sometimes shear ($S_H$)) on the land surface and measuring the travel time of the corresponding waves from the source to one or more geophones. These measurements are used to interpret subsurface conditions and materials. This travel time, along with distance between source and geophone(s), can also be interpreted to yield depth to refracting layer(s). The calculated seismic velocities can often be used to characterize some of the properties of natural and man-made subsurface materials.

This is a general procedure and does not address all the details and components of a seismic refraction survey. Please refer to the references provided for additional information.

## Objective

The specific objective varies depending on the project. It can be simply to reconnoiter subsurface conditions, or to provide detailed subsurface information. For example, rippability studies require very few geophones and a very simple analysis. On the other hand, detailed studies require very careful design of geophone spacing, source energy and location, accurate measurement of geophone elevations, and so on. In general, the basic outcome is a measurement of seismic wave velocities. Detailed studies will also provide a profile of the depth to refractors.

## Equipment

1. Seismic energy source. Four types of sources used by GEOVision include:

    1.1. Sledge hammers of various weights

    1.2. Mechanical or accelerated weight drop or impact devices, such as the Bison EWG-1, Geometrics Dynasource or a modified PEG-40Kg.

1.3. Projectile (gun) sources, such as the Betsy Seisgun, Betsy downhole percussion firing rod

1.4. Explosives

2. Multichannel seismograph, such as Geometrics Geode, OYO DAS-1, or equivalent. GEOVision uses 24 to 48 channel systems for detailed refraction surveys. Seismographs must provide for digital recording, and for signal enhancement (energy) stacking. Single - 12 channel systems are acceptable for simple surveys such as rippability studies.

3. 4 - 14 Hertz geophones (vertical for P-wave refraction studies, horizontal for S-wave studies), connected to the seismograph by cable. Geophone and take-out (electrical connection) spacing is determined by the depth of exploration and the resolution required

4. Trigger cable or radio link, to provide a timing signal to the seismograph at the time of source impact

5. Batteries to operate refraction system

Figure 1 is a sketch of the field layout for a typical refraction survey.

## Environmental Conditions

Seismic refraction data are affected by ground vibrations from a variety of sources. These include ambient sources such wind, water movement (such as waves breaking on a nearby beach), natural seismic activity, and rainfall on the geophones. They also include cultural sources such as vehicular traffic, construction equipment, nearby motors, aircraft, or blasting. Frozen ground can contribute a high-velocity near-surface path that will obscure the contribution of deeper layers.

Such sources should be minimized as much as possible. Where possible, refraction data should not be collected during high winds or rain, or while vehicles are passing.

## Calibration

Calibration of the multichannel seismograph is required. Calibration is limited to the timing accuracy of the recorder. GEOVision's Seismograph Calibration Procedure or equivalent should be used. Calibration must be performed on an annual basis.

**Measurement Procedure**

The specific procedure varies according to the objective for the survey, the design of the survey, and the method used to define the planar refractors. These are described in more detail in other references (1 - 6).

The most important considerations are:

1. Location of seismic refraction lines

2. Length and orientation of lines

3. Geophone spacing

4. Location of shots (sources)

5. Approach or interpretation method. These can include:

   5.1. Intercept-time or crossover method

   5.2. Delay-time methods and variations thereof

   5.3. Reciprocal methods, including:

      5.3.1. Common Reciprocal Method

      5.3.2. Generalized Reciprocal Method

   5.4. Ray-tracing methods

   5.5. Tomographic methods

Of these approaches, the two methods most often used by GEOVision for detailed refraction surveys are the Generalized Reciprocal Method (GRM) and the Tomographic Method. GRM is acknowledged to be superior to many other methods for modeling irregular dipping refractors and lateral velocity changes. Tomographic Methods are commonly used to image gradual velocity contacts and weathering profiles.

The general field procedures are as follows:

1. Check for adequate space to lay out a straight line in accordance with the survey design

2. Locate and position first geophone according to design and such that the location can be repeated or identified independently (the line should be referenced to absolute fiducials at several locations).

3. Mark geophone locations between endpoints and available intermediate fiducials at the design spacing. Locations must be surveyed to within 5% of the geophone interval (3" for 5ft spacing, and 6" for 10ft spacing). Elevations of geophone locations may be obtained from client-provided survey or from a level survey referenced to available site reference points. A level survey, if performed, shall be closed back to the available site reference points within 0.25ft.

4. Lay out geophone cable.

5. Place geophones at marked locations. Geophones must be vertical and well coupled to the ground using the spike provided. Where rock is exposed the spike may be replaced with a tripod base or rock plate.

6. Test geophones and cables for shorts or open circuits.

7. Set up source(s) at design locations. Shot locations must also be surveyed to within 5% of the geophone interval (3" for 5ft spacing, and 6" for 10ft spacing).

8. Place trigger cable.

9. Test seismic source and trigger cable.

10. Input survey geometry into seismograph.

11. Test noise level and set gains and filters.

12. Proceed with refraction measurements. Perform forward and reverse and offend shots as required by the interpretation method selected.

**Required Field Records**

1) Field log for each refraction measurement describing:

    a) Location of each geophone.

    b) Date and time of test.

    c) Tester or data recorder.

    d) Description of source (location, amplitude, number of stacks).

    e) Any gain or filtering by channel during recording.

    f) Any deviations from test plan and action taken as a result.

    g) File name as recorded on disk.

h) QA Review.

Much of the above information will be automatically recorded in the seismograph header at the time of recording (gains, filtering, and survey geometry) and need not be recorded on the paper log.

2) Flash drives, CDs or equivalent with backup copies of data on hard disk, labeled with line and measurement designation, record ID numbers, date, and tester name.

**Analysis and Interpretation**

Following completion of field work, the recorded digital records are processed by computer and interactively analyzed by an experienced geophysicist to produce plots and tables of P and $S_H$ wave velocity versus depth.

Again, the specific procedure varies according to the objective for the survey, the design of the survey, and the method used to define the planar refractors.

In general, GEOVision refraction data is processed with either the Generalized Reciprocal Method (GRM), one of the most advanced modeling methods currently available for seismic refraction data or the Tomographic Method. Processing steps consist of loading field records into a computer, picking the travel times of first arrivals, entering shot and spread geometry, phantoming data from all shots on a line to obtain one set of forward and reverse travel time curves for each refractor, and applying the GRM to obtain a depth section (model showing different geologic units and their velocities). The Tomographic Method requires a higher shot density than GRM. Processing steps consist of loading field records into a computer, picking the travel times of first arrivals and entering shot and spread geometry. Commonly a layer based, horizontal model is used as an initial base for the inversion routines. The inverted model is quality checked for geologic plausibility and RMS error data fit. Initial settings and input models are changed until the inverted model is of sufficient quality for interpretation.

Preliminary interpretations are carefully verified using available geologic and drilling data. If at all possible, GEOVision recommends performing P-S Suspension Logging or Downhole velocity survey in at least one borehole for a high-resolution constraint of the model. If such data is not available, the report will so mention.

**Report**

The final report will include the objective and scope of the survey, discussion of the geologic setting, any limitations of the survey, and any assumptions made. The field approach will be described including a description of equipment, procedures, and data acquisition parameters. The location of the seismic refraction line will be described along with a site map and the shot-point/geophone layout. Any corrections made to the field data will be discussed, including justification. The results of field measurements will be described including samples of raw data, and time-distance plots.

The methodology for picking first arrivals and for interpreting the results will be described along with any software program used. The interpreted results based on these methods will be presented along with any qualifications and alternate interpretations. These will include depth sections and seismic velocities.

Appropriate references for any supporting data will be provided.

The report will be signed by the California Professional Geophysicist responsible for the refraction survey and data interpretation, and QA Reviewed in accordance with GEOVision QA Procedures.

Professional Geophysicist_________________________Date___11-7-11________

QA Review_________________________Date___11-7-11________

References:


1. ASTM D5777 - 00(2006) “Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation”

2. Redpath, Bruce B. “Seismic Refraction Exploration for Engineering Site Investigations”, Explosive Excavation Research Laboratory, Livermore, CA, distributed by NTIS, US Dept. of Commerce, Springfield, VA 1973

3. “Geophysical Exploration for Engineering and Environmental Investigations”, Technical Engineering and Design Guides as adapted from the US Army Corps of Engineers, No.23, published by ASCE Press, Reston, VA 1998

4. Dobrin, M.B. 1960 *Introduction to Geophysical Prospecting*. 2nd Edition. McGraw-Hill Book Co. Inc, New York

5. Telford, W.M., et al, 1976 *Applied Geophysics* Cambridge University Press

6. Milsom, J. 1989 *Field Geophysics* Open University Press, Milton Keynes

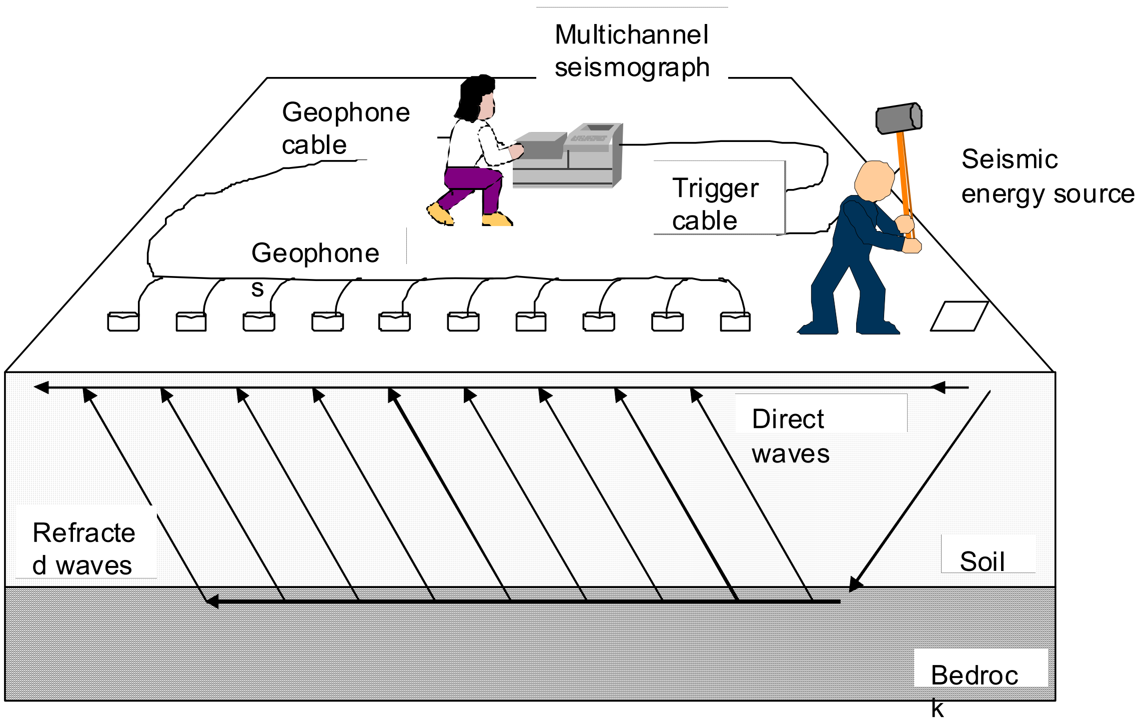



**Figure 1 FIELD LAYOUT OF A MULTICHANNEL SEISMOGRAPH SHOWING WAVE PATHS**

**PROCEDURE FOR**

**MULTI-CHANNEL ARRAY SURFACE WAVE (MASW) METHOD**

**Revision 1.1, Reviewed 12/10/15**

## Background

This procedure describes a method for determining shear wave velocity ($V_S$) profiles, based on surface wave dispersion measurements made on the ground surface. The MASW Method consists of collecting multi-channel seismic data in the field, then applying a wavefield transform to obtain the dispersion curve, followed by using iterative forward or inverse modeling to back-calculate the variation of $V_S$ with depth.

This is a general procedure and does not address all the details and components of MASW testing. A detailed description of the MASW method is given by Park, 1999a and 1999b.

## Objective

The outcome of this procedure is an equivalent 1-D or 2-D model of $V_S$ versus depth for the area tested. A 2-D model is obtained by combining 1-D inversions of surface wave dispersion data acquired at regular intervals along a profile. Results are presented in graphic and tabular format.

## Instrumentation

1. Digital 24-channel, 24-bit fixed point or 21-bit floating point seismograph (Geometrics Geode seismograph, or equivalent)
2. Laptop computer, to download data from the seismograph, with USB thumb drive or CDRW to write backup CDRs.
3. 24 or more geophones, 4.5Hz or less resonant frequency, such as OYO Geospace 4.5 Hz geophones. Other frequencies of geophones may be used, depending on the material and depth of investigation. Geophones can optionally be mounted on a landstreamer, depending on site conditions.
4. Geophone cables, with length and take-out spacing commensurate with desired depth of investigation.
5. 12 V battery to operate seismic instrumentation.
6. Seismic sources as necessary for desired profiling depth, including hand-held and sledge hammers of various weights, elastic weight drop, mechanical shaker, eccentric mass oscillator, heavy equipment such as a bulldozer, dropped weight, vibroseis truck or other equipment capable of generating vertical dynamic loads on the surface.

## Environmental Conditions

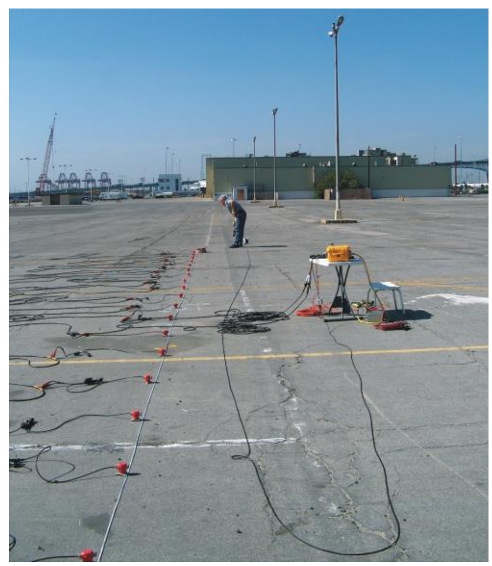
Ground vibrations from a variety of sources affect surface wave velocity measurements. These include ambient sources such as water movement (such as waves breaking on a nearby beach) and wind. Cultural noise sources such as vehicular traffic, construction equipment, rotating machinery, or blasting may also degrade data quality. When possible, MASW testing should be conducted when cultural noise levels are at a minimum.

For a 1-D MASW depth sounding, the minimum area of open, relatively flat terrain required for the MASW array is three to four times the profile depth. 2-D MASW profiles should be placed in open areas with only gentle topography. If the geophones are mounted on a landstreamer, vehicle or ATV access will be required to tow the landstreamer.

## Calibration

The seismograph should be calibrated yearly. For best results the geophones should be the same model and frequency, and closely matched in phase output, but calibration (sensitivity) is not required.

## MASW Field Procedure



***MASW Field Setup***

The specific procedure varies according to the objective for the survey. The most important consideration is the depth investigation. This determines the frequency range of the seismic source and length of array required. The length of the geophone array should be, at a minimum, 2 to 3 times the desired depth of the investigation.

The MASW field layout is similar to that of the seismic refraction technique. Twenty four, or more, geophones are laid out in a linear array with 1 to 2m spacing and connected to a multi-channel seismograph. This technique is ideally suited to 2D $V_S$ imaging, with data collected in a roll-along manner similar to that of the seismic reflection technique. Geophones can also be mounted on a landstreamer and towed along the survey line. The source is offset at a predetermined distance from the near geophone usually determined by field testing. Following are the basic steps:

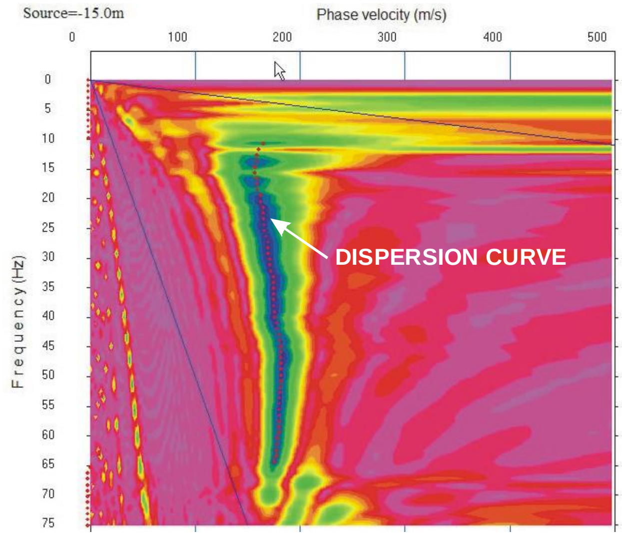
1. The MASW technique typically uses 24 or more 4.5Hz geophones arranged in a linear array.
2. For a 1-D MASW sounding, check for adequate space for the array and select centerline and direction. A flat stretch of ground 3 to 4 times the depth of

investigation, centered on the target sounding location is best. 100m is minimum. For a 2-D MASW profile, check that vehicle access is possible if towing a landstreamer or using a vehicle mounted energy source.

3. Avoid concrete slabs, utility corridors, and sewer lines, as possible
4. Layout survey ropes and mark stationing as necessary. If necessary, a deviation off line up to 5% is tolerable (10m of 200m line). Optionally a total station may be used to survey sensor locations. Geophone spacing should be such that the length of the receiver array is, at a minimum, 2 to 3 times the desired depth of investigation.
5. Setup seismograph. Select digitizing rate and record length to match depth/frequency desired. Be sure to turn off or minimize any filtering, except antialiasing filters.
6. Acquire sample data and adjust input levels if necessary.
7. Activate source for measurements. For impact sources, such as a sledgehammer, several averages are usually required - 5 to 10 is typical. Multiple source locations may be occupied for a 1-D sounding.
8. Download and visually confirm data on laptop. Check every channel for bad connections, and excess noise. Store in separate files or directories with unique names. Beware of overwriting files. Backup data to CDRW or thumb drive before departing site.
9. Record required information on field log or in field notebook. This includes file name, location and orientation of array, location of each sensor within the array, and any other comments.
10. Stake and mark center or ends of MASW array if necessary for later surveying. Measure and record azimuth of array line if ncessary.
11. Backup data to hard disk on laptop PC.

## Data Analysis and Interpretation

The Rayleigh wave dispersion curve is obtained by a wavefield transformation of the seismic record such as the f-k or $\tau$-p transforms. These transforms are very effective at isolating surface wave energy from that of body waves. The dispersion curve is picked as the peak of the surface wave energy in slowness (or velocity) – frequency space as shown. One advantage of the MASW technique is that the wavefield transformation may not only identify the fundamental mode but also higher modes of surface waves. At some sites, particularly those with large velocity inversions, higher surface wave modes may contain more energy than the fundamental mode. 2-D images of $V_S$ versus depth along a profile are constructed by combining 1-D inversions of dispersion data collected at regular intervals along the profile. Several commercial software packages are available for the analysis of MASW data and other surface wave data.




***Wavefield Transform of MASW data***

## Reporting

The final report will include the objective and scope of the survey, discussion of instrumentation and procedures in the field and lab. The location of the MASW arrays/profiles will be provided on a site map. If the MASW technique is utilized to obtain 1-D soundings of $V_S$ versus depth, then the composite dispersion curve and/or compact dispersion curve will be provided. The fit of the theoretical dispersion curve to the composite or compact dispersion curve will be shown. The shear wave velocity profile determined from each array is presented in graphic and tabular format. For 2D MASW imaging investigations, it is only necessary to provide the 2-D image of $V_S$ versus depth along the profile and an ASCII file containing the inverted 1-D $V_S$ models used to generate the image.

Assumptions and limitations of the results will be discussed. Supporting references will be listed as necessary.

## Deviations From Above Written Methods and Procedures

Variations on the basic procedure should be documented, including receiver spacing, source used, receiver sensors, and duration of recording.

## Required Field Records

1) Field log/notebook for MASW array/profiles showing
   a) Location and orientation of array
   b) Date of test
   c) Field personnel
   d) Instrumentation
   e) Data acquisition parameters including record length, sample rate, receiver spacing
   f) For each seismic record document file name, receiver array location, source location, source type, number of source averages
   g) Any deviations from test plan and action taken as a result

Registered Geophysicist_______________________________Date___12-10-2015_

QA Review_______________________________Date___12-10-2015_

## References

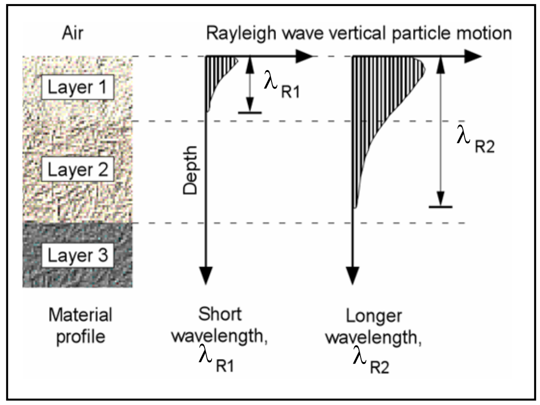
Park, C.B., Miller, R.D. and Xia, J., 1999a, "Multimodal analysis of high frequency surface waves", *Proceedings of the Symposium on the Application of Geophysics to Engineering and Environmental Problems '99*, 115-121.

Park, C.B., Miller, R.D. and Xia, J., 1999b, "Multichannel analysis of surface waves", Geophysics, Vol 64, No. 3, 800-808.

**PROCEDURE FOR PASSIVE SURFACE WAVE METHODS INCLUDING ARRAY MICROTREMOR AND REFRACTION MICROTREMOR (ReMi)**

**Reviewed 2/10/06**

## Background




Active and passive surface wave techniques are in-situ seismic methods for determining shear wave velocity ($V_S$) profiles. Testing is performed on the ground surface, allowing for less costly measurements than with traditional borehole methods. The basis of surface wave techniques is the dispersive characteristic of Rayleigh waves when traveling through a layered medium. Rayleigh wave velocity is determined by the material properties (primarily shear wave velocity, but also to a lesser degree compression wave velocity and material density) of the subsurface to a depth of approximately 1 to 2 wavelengths. As shown in the adjacent diagram, longer wavelengths penetrate deeper and their velocity is affected by the material properties at greater depth. Surface wave testing consists of measuring the surface wave dispersion curve at a site and modeling it to obtain the corresponding shear wave velocity profile.

Passive surface wave techniques measure noise; surface waves from ocean wave activity, traffic, factories, etc. These techniques include the array microtremor and refraction microtremor (REMI) techniques. Array choices are dictated by availability, configuration, and orientation of space.

*Depth of Investigation*

Passive surface wave techniques can often image shear wave velocity structure to depths of over 100m, given sufficient noise sources and space for the receiver array. Large passive arrays, utilizing long-period seismometers with GPS clocks have been used to image shear wave velocity structure to depths of several kilometers.

## Objective

The outcome of this procedure is an equivalent 1-D model of $V_S$ versus depth for the area tested. Results are presented in graphic and tabular format.

## Array Microtremor

### Instrumentation

1. Digital 24-channel, 24-bit fixed point or 21-bit floating point seismograph with sufficient memory to hold at least 30 seconds of data (Geometrics StrataView R or Geode seismograph or equivalent)

2. Laptop computer, to download data from the seismograph, with USB thmb drive or CDRW to write backup CDRs.

3. 24 or 48 geophones of 4.5Hz or less resonant frequency, such as Mark Products 4.5 hz geophones.

4. Geophone cables, at least 100m with take-outs commensurate with desired depth of investigation

5. 12 V battery or AC power supply to operate seismographs

### Environmental Conditions

The primary requirement for passive surface wave methods is adequate space, and sufficient background noise energy for the data. Unlike active methods (see GEOVision SASW Procedure), these methods benefit from cultural noise.

As a minimum, the area of open, relatively flat terrain required for the array about equal the profile depth (length and width). The ground surface should be exposed where the geophones are placed. Very soft, saturated ground may reduce signal amplitude. Placing the geophones on concrete tiles may improve geophone coupling in these situations.

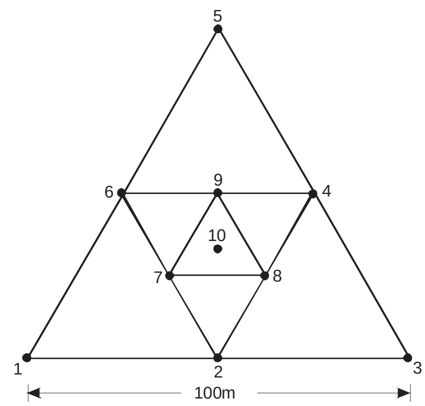
### Calibration

For best results the geophones should be the same model and frequency, and closely matched in phase output, but calibration (sensitivity) is not required.

## Array Microtremor Field Procedure

The specific procedure varies according to the objective for the survey. The most important consideration is the depth of investigation. This determines the frequency range of the seismic source and length of array required.

The array microtremor technique typically uses 4 or more 4.5- or 1-Hz geophones arranged in a two-dimensional array. The most common arrays are the triangle, circle, semi-circle and "L" arrays. The triangle array, which consists of several embedded equilateral triangles, is often used as it provides good results with a relatively small number of geophones. With this array the outer side of the triangle should be at least as long as the desired depth of investigation. Typically, fifteen to twenty 30-second noise records are acquired for analysis.




***Example Triangle Array Geometry – 10 channels***

1. Check for adequate space for the array and select centerline and direction. A flat stretch of ground 200m diameter, centered on the target sounding location is best. 100m is minimum.

2. Avoid concrete slabs, utility corridors, and sewer lines, as possible

3. Layout survey ropes from common centerline to make sure each leg is equal length. If necessary, a deviation off line up to 2% is tolerable (4m of 200m line). Optionally a total station may be used to survey sensor locations.

4. Setup seismograph. Select digitizing rate and record length to match depth/frequency desired. Be sure to turn off or minimize any filtering, except antialiasing filters (high-cut 250Hz is OK).

5. Acquire sample data and adjust input levels if necessary.

6. Download and visually confirm data on laptop. Check every channel for bad connections, and excess noise.

7. Record required information on field log. This includes file name, location and orientation of array, location of each sensor within the array, and any other comments.

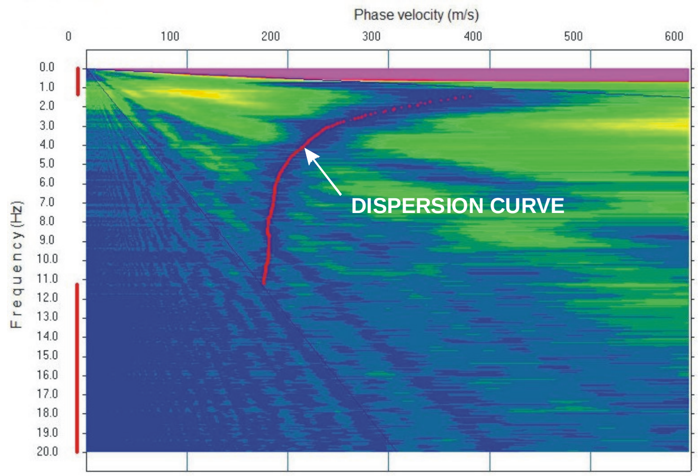
8. Record data for full duration. 15 seconds is minimum. For deep imaging, several minutes are required. Do not stack data. Clear stack memory every time.

9. Repeat 10 to 20 times for best statistical average

10. Download data to PC and store in separate files or directories with unique names. Beware of overwriting files. Backup data to CDRW or thumb drive before departing site.

**Data Analysis and Interpretation**

The spatial autocorrelation (SPAC) technique is one of several methods that can be used to estimate the Rayleigh wave dispersion curve. A first order Bessel function is fit to the SPAC function to determine the phase velocity for particular frequency. The image shown below shows the degree of fitness of the Bessel function to the SPAC function for a wide range of phase velocity and frequency. The dispersion curve, is the peak (best fit), as shown in the figure below.




***Dispersion Curve from Array Microtremor Measurements***

## Refraction Microtremor (ReMi)

### Instrumentation

1. Digital 24-channel, 24-bit fixed point or 21-bit floating point seismograph with sufficient memory to hold at least 30 seconds of data (Geometrics StrataView R or Geode seismograph or equivalent

2. Laptop computer, to download data from the seismograph, with USB thmb drive or CDRW to write backup CDRs.

3. 24 or 48 geophones of 8Hz or less resonant frequency, such as Mark Products 4.5 hz geophones.

4. Geophone cables, at least 100m with take-outs commensurate with desired depth of investigation

5. 12 V battery or AC power supply to operate seismographs

### Environmental Conditions

Like all surface wave methods, the primary requirement for passive surface wave methods is adequate space, and sufficient background noise energy for the data. Unlike active methods (see GEOVision SASW Procedure), these methods benefit from cultural noise.

As a minimum, the area of open, relatively flat terrain required for the array is twice the profile depth (length and width). Very soft, saturated ground may reduce signal amplitude. Placing the geophones on concrete tiles may improve geophone coupling in these situations.

### Calibration

For best results the geophones should be the same model and frequency, and closely matched in phase output, but calibration (sensitivity) is not required.

**Refraction Microtremor (ReMi) Field Procedure**

The specific procedure varies according to the depth objective for the survey. The most important consideration is the depth investigation. This determines the frequency range of the seismic source and length of array required.

The refraction microtremor (REMI) technique uses a field layout similar to the seismic refraction method (hence its name). Twenty-four geophones are laid out in a linear array with a spacing of 5 to 10m, or more, and fifteen to twenty 30-second noise records are acquired.

The photo below shows a typical setup for ReMi measurements, with sensors equally spaced in a linear pattern. The general field procedure is as follows:

***Refraction Microtremor Array Layout***

1. Check for adequate space for the array and select centerline and direction. A flat stretch of ground 200m long, centered on the target sounding location is best. 100m is minimum.

2. Avoid concrete slabs, utility corridors, and sewer lines

3. Layout survey ropes from common centerline. If necessary, a deviation off line up to 5% is tolerable (10m of 200m line)

4. Setup seismograph. Select digitizing rate and record length to match depth/frequency desired. Be sure to turn off or minimize any filtering, except antialiasing filters (high-cut 250Hz is OK).

5. Acquire sample data and adjust input levels if necessary.

6. Download and visually confirm data on laptop. Check every channel for bad connections, and excess noise.

7. Record required information on field log. This includes file name, location and orientation of array, location of each sensor within the array, and any other comments.

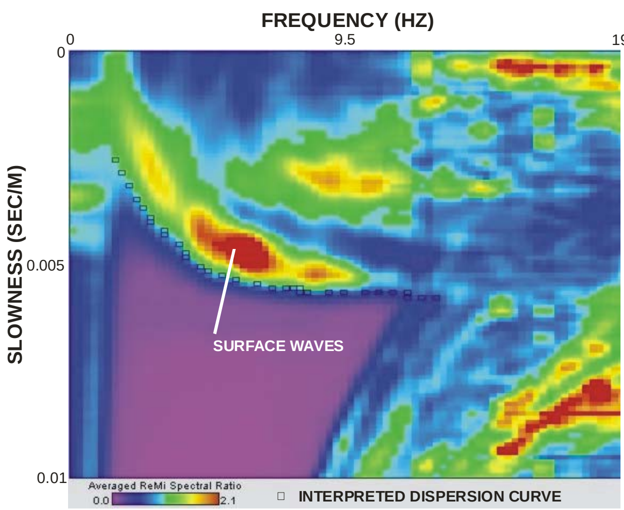
8. Record data for full duration. 15 seconds is minimum. For deep imaging, several minutes may be required. Do not stack data. Clear stack memory every time.

9. Repeat 10 to 20 times for best statistical average

10. Download data to PC and store in separate files or directories with unique names. Beware of overwriting files. Backup data to CDRW or thumb drive before departing site.

## Data Analysis and Interpretation

A slowness-frequency (p-f) wavefield transform is used to separate Rayleigh wave energy from that of other waves. Because the noise field can originate from any direction, the wavefield transform is conducted for multiple vectors through the geophone array, all of which are summed. The dispersion curve is defined as the lower envelope of the Rayleigh wave energy in p-f space. The SPAC technique can also be used to extract the surface wave dispersion curve from linear array microtremor data providing there are omni-directional noise sources.




***Wavefield Transform of REMI Data***

## Passive Surface Wave Data Analysis and Interpretation

Once the dispersion curve is generated from the passive surface wave data it can be combined with dispersion curves from active surface wave data for modeling. Dispersion data is modeled using iterative forward and/or inverse modeling software. During modeling a $V_S$ profile is found whose theoretical dispersion curve is a close fit to the field data.

The parameters in the model are layer thickness, $V_S$, $V_P$, and density. Because they are the most sensitive parameters, only $V_S$ and layer thickness are usually adjusted. Background geologic information from borings may be used to refine the model. P-wave velocities are specified that are typical of saturated or unsaturated sediments or rock. Typical densities of soil or rock are used.

For sites at which the shear wave velocity generally increases with depth, fundamental-mode Rayleigh wave models are adequate for modeling the dispersion curve. At sites with velocity inversions or large velocity contrasts, models that take into account body waves and/or higher modes of surface wave propagation are necessary.

The theoretical model used to interpret the dispersion assumes horizontally layered, laterally invariant, homogeneous-isotropic material. Although these conditions are seldom strictly met at a site, the results of active and/or passive surface wave testing provide a good "global" estimate of the material properties along the array. The results may be more representative of the site than a borehole "point" estimate.

## Passive Surface Wave Reporting

The final report will include the objective and scope of the survey, discussion of instrumentation and procedures in the field and lab. The location of the arrays will be provided on a site map. For each array the composite dispersion curve and/or compact dispersion curve will be provided. The fit of the theoretical dispersion curve to the composite or compact dispersion curve will be shown. The shear wave velocity profile determined from each array is presented in graphic and tabular format.

Assumptions and limitations of the results will be discussed. Supporting references will be listed as necessary.

**Deviations From Above Written Methods And Procedures**

If linear (ReMi), "L" or triangular (array) array is not used, the array geometry should be specified. If different receiver spacings are not in line, the direction will be recorded.

**Required Field Records**

1) Field log for each surface array sounding showing
   a) Location and orientation of array
   b) Date of test
   c) Field personnel
   d) Instrumentation
   e) For each receiver spacing: distance between receivers, direction, source, frequency span and resolution, number of averages
   f) Any deviations from test plan and action taken as a result

This procedure has been reviewed and approved by the undersigned:

Professional Geophysicist________________________Date Feb 13. 2006

QA Review________________________Date Feb 13. 2006

# QUALITY ASSURANCE PROGRAM

## GEO*Vision* Inc.

Revision 0 August 11, 1998
Revision 0.10 May 5, 2005
Revision 1.0 June 1, 2007
Revision 1.1 November 21, 2007
Revision 2.0 October 15, 2014

President________________________________ 10-15-14
John G. Diehl Date

Quality Manager________________________________ 10-15-14
John G. Diehl Date

## *GEOVision QUALITY ASSURANCE PROGRAM REVISION LOG*

| DATE | REVISION NUMBER | REASON FOR CHANGE | APPROVED |
|---|---|---|---|
| | | | |
| 8/11/1998 | 0.00 | NEW GEOVISION PROGRAM | JGD |
| | | MINOR CORRECTIONS TO TEXT | JGD |
| | | REVISED FROM GEOVISION DIV OF AGBABIAN | |
| | | TO GEOVISION DIVISION OF | |
| | | BLACKHAWK GEOMETRICS | |
| 5/5/2005 | 0.10 | REVISED TITLE PAGE | JGD |
| | | FROM GEOVISION DIVISION OF | |
| | | BLACKHAWK GEOMETRICS TO | JGD |
| | | GEOVISION INC. | JGD |
| 6/1/07 | 1.00 | MAJOR REVISION | |
| | | 1. Added Reference Section in order to cross-reference other relevant GEOVision policies | JGD |
| | | 2. Updated Sections 1.0 and 2.2 and added Reference 1 to cross reference “GEOVision FY 2003 Reorganization and Management Responsibility” | JGD |
| | | 3. Updated Section 2.3 to document GEOVision Standard Procedures as digital references, and maintenance of them | JGD |
| | | 4. Updated 2.4, 10 and 11.2 to cross reference “GEOVision FY 2003 Reorganization and Management Responsibility” | JGD |
| | | 5. Update 11.5 – allow PBA for test result evaluation | JGD |
| | | 6. Update 12.1 – add resistivity meters | JGD |
| | | 7. Update Sections 13, 17 and 18.1 for modern digital data and file management | JGD |
| | | 8. Added 16.2 – 10CFR21 procedure | JGD |
| | | 9. Update 18.2 – delete reference to QAP Audit Form | JGD |
| | | 10. Created this revision log | JGD |
| 11/21/07 | 1.1 | Revised 16.2 to reflect new independent 10CFR21 procedure | JGD |
| 10/15/14 | 2.0 | REVISION | |
| | | 1. Remove most of Section 3 DESIGN CONTROL. Does not apply to geophysical services | JGD |
| | | 2. In section 5, remove reference to 9.3 | JGD |
| | | 3. Add to definition of administrative processes for reviewing and approving documents, and revision control. This included changes to 2.3, 2.6, and 5.0 | JGD |
| | | | |

# *Table of Contents*

*Introduction*

This document describes the Quality Assurance Program (QAP) of GEOVision, Inc. It is the intention of GEOVision by this program to comply with the essential elements of ASME NQA-1-1994 "Quality Assurance Requirements for Nuclear Facility Applications" and Title 10 of the Code of Federal Regulations, Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Processing Plants".

## 1. ORGANIZATION

Figure 1 indicates the organization of GEOVision's QAP. The President delegates the QA Manager with responsibility for preparing and maintaining the QAP for GEOVision. He has the authority to:

a) Audit process procedures, witness any process procedures, or review any or all work results in order to identify quality problems;
b) Delegate QA review responsibilities
c) Initiate, recommend, or provide solutions to quality problems through designated channels;
d) Verify implementation of solutions
e) Assure that further processing, delivery, installation, or use is controlled until proper disposition of non-conformance, deficiency, or unsatisfactory condition has occurred.

Within GEOVision, basic quality is achieved and maintained by those assigned responsibilities for performing the work, principally the Project Managers. The Project Manager is assigned at the time each Job Order is opened (see example in Appendix). Quality is achieved by establishing proper procedures and standards of performance for quality work, by proper training, and by QA review of all work performed prior to submittal of results. Reference 1, "GEOVision FY 2003 Reorganization and Management Responsibility", more clearly outlines the training, scope and responsibilities for GEOVision's QA program, particularly on page 3, "QA Managers".

## 2. QUALITY ASSURANCE PROGRAM

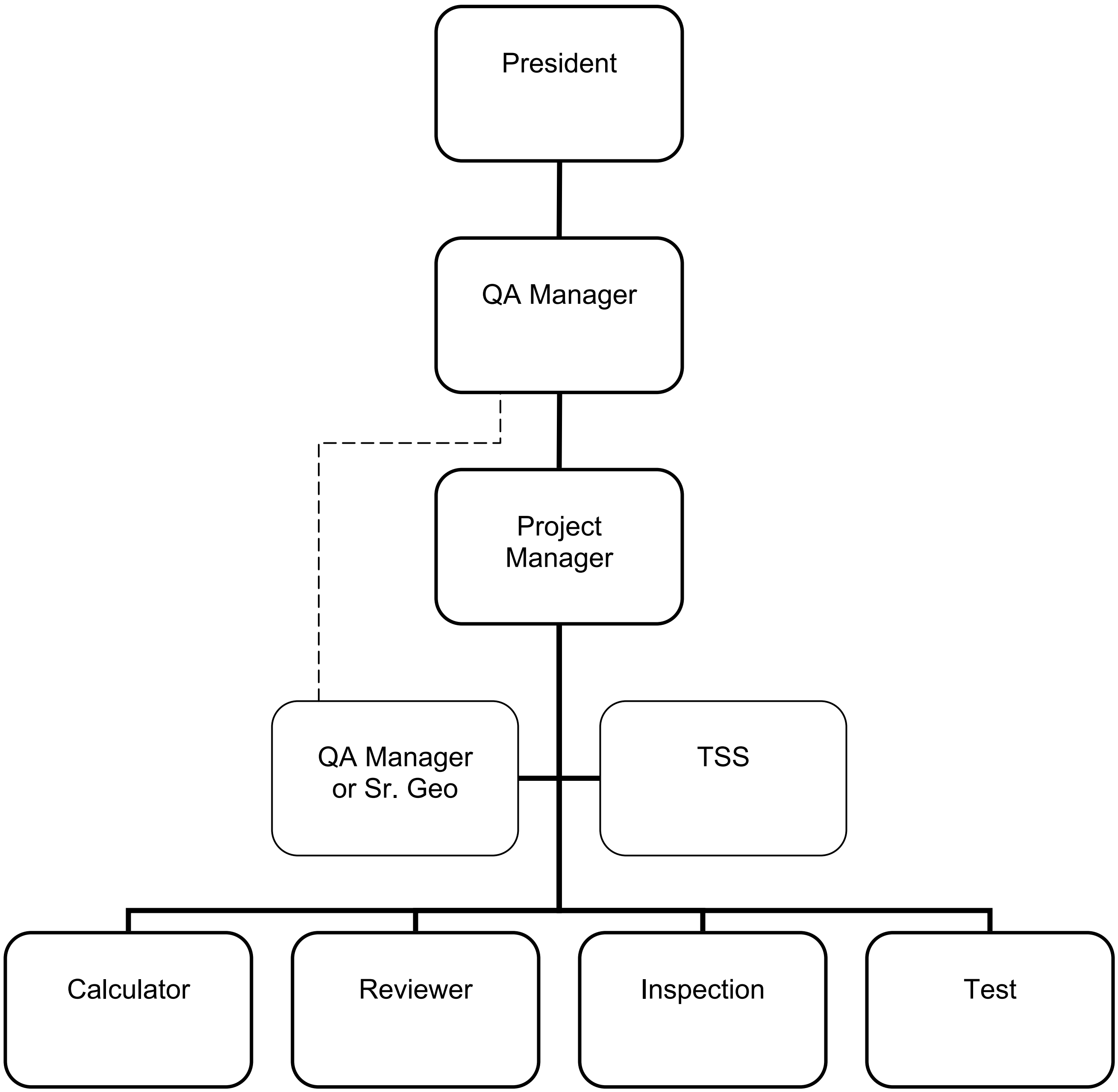
The QAP of GEOVision has been established and maintained since 1995. This QAP document is the written description of the program. This standard approved QAP is applicable to all projects, unless superseded by a Supplemental QAP for a specific project and approved by the client.

### *2.1 Indoctrination*

All employees will be provided a copy of the QAP at the time of hiring. Documentation of each employee's receipt of the QAP is indicated by a copy of the signature page showing the release date and revision date. A copy of the signature page is kept in each employee's personnel file.

**GEOVISION**

# QUALITY ORGANIZATION




TSS = Team Support Services

It is the responsibility of each Project Manager to brief project personnel of the QA requirements and procedures for each project.

### *2.2 Training*

In addition to formal education requirements, training activities will be conducted as required to qualify personnel to perform Geophysical Services, Testing Services, and Engineering Services. At GEOVision, such training, for the most part, takes place in the form of "On-the-Job" training with emphasis on first-hand experience gained through actual performance of projects. A more detailed description is provided in Reference 1 "GEOVision FY 2003 Reorganization and Management Responsibility".

### *2.3 Service Procedures*

As necessary depending on the service being provided, quality control is further maintained through careful design and development of proper service procedures, or application of existing standard procedures (such as ASTM standard procedures). The use of specific procedures is left to the Project Manager. However, a repository of standard GEOVision procedures is provided on the main GEOVision file server under "Procedures", and unless otherwise provided or justified, these procedures must be used. It is the responsibility of the Senior Geo (Ref 1) to maintain these procedures while documenting changes (per section 2.6), and it is the responsibility of the QA Manager to ensure that procedures are properly preserved with recent backups available.

### *2.4 QA Review of Completed Projects*

All projects are subject to QA review. Approval by a QA reviewer is required prior to billing authorization. QA approval is determined by evaluating:

a) Required documents
b) Criteria conformance (established by approved test procedures, if required)
c) Instrument calibration (if required)
d) Accuracy
e) Appearance

If the QA reviewer is not satisfied, he/she will not authorize billing and will submit his/her recommendations for corrective action on the Corrective Action Request Form (see example in Appendix). If he/she is satisfied, billing is authorized based on QA approval. Evidence of QA Review is indicated with initials on the Billing Authorization Form as follows.

**QC REVIEWED**

BY____________________

DATE_________________

More details about QA review policy are provided in Reference 1 "GEOVision FY 2003 Reorganization and Management Responsibility".

### 2.4.1 Qualification of Personnel

QA review must be performed by someone other than the person performing the work. In general, QA review can be performed by the Project Manager provided the Project Manager was not the person performing the field procedures, data analysis, or processing, and provided he/she meets the minimum qualifications. The following are the minimum qualifications for persons performing QA review of completed work by category.

#### 2.4.1.1 Geophysical Services

Geophysical service results may be reviewed by any California Registered Geophysicist (R.G.) or any Geophysicist with at least 5 years experience performing the work that is being inspected or reviewed.

#### 2.4.1.2 Testing Services

Testing service results may be reviewed by any California Registered Professional Engineer (P.E.) or any Engineer with at least 5 years experience performing the work that is being inspected or reviewed.

#### 2.4.1.3 Engineering Services

Engineering service results may be reviewed by any California Registered Professional Engineer (P.E.) or any Engineer with at least 5 years experience performing the work that is being inspected or reviewed (see Part 3.2).

## *2.5 Triennial Review Program*

The GEOVision QAP is reviewed triennially by the QA Manager. The program is reviewed for adequacy in view of changing client needs and project requirements. The results of the internal audit are summarized in an internal memo. Corrective actions are addressed in Section 2.6.

## *2.6 Process for Maintaining Reviewing and Updating Documents under this Program*

The process for reviewing, approving and updating documents controlled under this program includes the following steps.

- New procedures are initiated by a Senior Geophysicist. Corrective action is initiated either through internal review (such as section 2.5) or through external client audit
- Changes are made in keeping with those recommended actions or they are addressed through an internal memorandum. Both new procedures and revised procedures are signed by the initiator, and approved by the QA Manager.
- Changes are documented in a Revision Log, such as beginning on page 2 of this QA Program. Each procedure shall have its own Revision Log. All changes are approved by the QA Manager.

# 3. DESIGN CONTROL

Design control measures do not apply to Geophysical or Testing Services.

# 4. PROCUREMENT DOCUMENT CONTROL

Procurement for supplies or services for projects (non-overhead items) will include the following items as applicable:

## *4.1 Scope of Work*

This is a statement of the work to be performed by the supplier. It is typically written by the PM or his/her designee.

## *4.2 Technical Requirements*

Technical requirements shall be specified and shall include specific drawings, specifications, codes, standards, regulations, procedures, instructions, or other design criteria. Revisions to these requirements shall also be included. Technical requirements will allow for the test, inspection, or review by GEOVision project personnel for the purpose of monitoring and evaluating supplier performance.

## *4.3 Quality Assurance Program Requirements*

Procurement documents must require that the Supplier have a documented quality assurance program that implements all or part of this program to the extent required by the client or the project.

## *4.4 Documentation*

Procurement documents shall identify:

a) What documentation is required of the supplier, if any
b) Whether the documentation must be submitted for information, review, or approval prior to continuation
c) When the documents are due
d) How long records, especially quality assurance records, should be kept

The Project Manager must sign all procurement documents. Copies of procurement documents must be stored in the Project File as well as the accounting files.

## *4.5 Non-conformances*

The Project Manager or his/her designee will evaluate services or products received from suppliers. Those services or products that do not conform to the procurement requirements will be reported in a written memorandum to the supplier, with a copy for the Project Manager, describing the errors or deficiencies. The supplier will be allowed to correct the errors or deficiencies by modification, repair, or replacement, or GEOVision will satisfy the required services or products by other means or suppliers. The procurement document will indicate this option.

## *4.6 Procurement Document Review*

Procurement documents must be reviewed and signed by the Project Manager. This includes all change orders. Change orders will be reviewed for their effects on the project including the design process and the quality. Change orders will be filed with the original procurement documents.

# 5. INSTRUCTIONS, PROCEDURES, DRAWINGS

Activities affecting quality will be prescribed by and performed in accordance with the latest revision of documented instructions, procedures, or drawings of a type that is appropriate to the circumstances. These documents will include or reference appropriate quantitative or qualitative acceptance criteria for determining whether the prescribed activities have been satisfactorily accomplished.

# 6. DOCUMENT CONTROL

The preparation, issue, or change of documents described in Section 5 will be controlled in the following way:

## *6.1 Document Preparation*

All documents specifying requirements or activities affecting quality for a specific project will be keyed to that project by the assignment of a number starting with the Project or Job Number. For example, Purchase Orders for project 9801 will begin PO 9801-XXXXXX-01, where XX.. is the date in YRMODY format, and so on. Field Procedures for the same project will begin FP 9801-01, and so on. Internal drawings will be labeled similarly Dwg 9801-01, and so on. External drawings for clients may carry a number assigned by the client, and therefore will be controlled in other ways.

The Project Manager is responsible for developing and approving such documents. In doing so he/she may choose to use documents developed for another similar project (see also Section 11.2). However, he/she is responsible for making sure the documents are adequate, complete, and appropriate for his/her project. His/her initials in the appropriate place on the document will indicate his/her approval.

## *6.2 Document Changes*

Once documents have been approved for use on a project they may not be changed without approval by the Project Manager. Major changes will require a written justification. If the documents have also been approved by the client, the changes must also be approved by the client. The client will have access to the same written justification.

# 7. CONTROL OF PURCHASED ITEMS AND SERVICES

See Section 4.

# 8. IDENTIFICATION AND CONTROL OF ITEMS

Whenever items, such as equipment or supplies, are procured for carrying out Geophysical Services, Testing Services, or Engineering Services, the Project Manager is responsible to ensure that the items are properly identified (see also Section 12), and that such identification is maintained on the items or in documents traceable to the items.

# 9. CONTROL OF PROCESSES

## *9.1 Process Control*

Instructions, procedures, drawings, checklists, or other appropriate means will control all processes affecting quality.

## *9.2 Special Processes*

Special processes are processes that control or verify quality, such as those used in welding, heat treating, or non-destructive testing. Special processes will be performed by qualified personnel using qualified procedures (see also Sections 5 and 6) in accordance with specified requirements.

### 9.2.1 Responsibility

It is the responsibility of the Project Manager to identify special processes and those procedures affecting quality, and to ensure that qualified personnel are assigned and qualified procedures are followed.

### 9.2.2 Acceptance Criteria

Requirements of applicable codes and standards shall be referenced in the procedures or instructions. Appropriate quantitative or qualitative acceptance criteria for the process will be included.

# 10. INSPECTION

Inspections may be required to verify conformance of an item or activity to specified requirements. Such inspections have already been described in Sections 2.3, 2.4, 3.3, and 4.6, and are further described in Reference 1, “GEOVision FY 2003 Reorganization and Management Responsibility”. This section covers all other inspections deemed appropriate and necessary by the Project Manager.

## *10.1 Inspection requirements*

Inspection requirements and acceptance criteria shall include specified requirements contained in applicable design documents or other pertinent technical documents approved by the Project Manager. Inspection activities shall be documented and controlled

## *10.2 Personnel*

Inspection personnel shall be individuals who do not report directly to the immediate supervisors responsible for the work being inspected.

Each person who verifies conformance of work activities for the purposes of acceptance shall be qualified to perform the assigned inspection task.

### 10.3 Inspection Hold Points

Mandatory hold points beyond which work shall not proceed without specific consent or approval by a designated representative shall be so indicated in the appropriate documents. Non-conformance that results in a hold on work will be documented in a Corrective Action Request Form (see example in Appendix).

### 10.4 In-process Inspection

In-process inspection may be necessary for critical processes such as during construction. The Project Manager may specify direct inspection, indirect monitoring (of processing methods, equipment, personnel), or both in order to maintain control.

### 10.5 Final Inspection

Final inspection is covered by Section 2.4. This includes a review of results, records, and resolution of all nonconformances identified in prior inspections. Acceptance will be documented and approved by the Project Manager.

## 11. TEST CONTROL

Tests required to collect data, such as for site characterization or design input, shall be planned, executed, documented, and evaluated.

Tests may also be required to verify conformance of an item or computer program to specified requirements and/or to demonstrate satisfactory performance for service. These also shall be planned, executed, documented, and evaluated.

In all tests, characteristics to be tested and test methods or procedures to be employed shall be specified by the Project Manager (see also Section 6.1).

### 11.1 Test Requirements

Test requirements and acceptance criteria shall be provided or approved by the Project Manager or the organization responsible for the design of the item to be tested. These shall be based on specified requirements contained in applicable design or other pertinent technical documents.

### 11.2 Test Procedures

Test procedures shall include or reference test objectives or provisions for assuring that prerequisites for the given test have been met, that adequate instrumentation is available and used, that necessary monitoring is performed, and that suitable environmental conditions are maintained. Prerequisites can include calibrated instrumentation, appropriate equipment, trained personnel, condition of test equipment, condition of item to be tested, suitable environmental conditions, and provisions for data acquisition.

Standard procedures are provided for in section 2.3. In lieu of specially written test procedures, it is acceptable to use appropriate sections of ASTM procedures, supplier manuals, maintenance instructions, or client instructions. Such documents must include adequate instructions to assure the required quality of work.

### *11.3 Test Results*

Test results must be documented and evaluated by the Project Manager or his/her designee to ensure that test requirements have been satisfied. Copies will be filed in the Project File (section 13).

### *11.4 Computer Programs*

If computer programs that are not certified or approved under applicable standards are to be used for a project, verification tests shall demonstrate the capability of a computer program to produce valid results for test problems encompassing the range of permitted usage defined by the program documentation. Acceptable test methods include:

a) Hand calculations
b) Calculations using comparable proven programs
c) Empirical data and/or information from technical literature

### *11.5 Test Records*

Test records as a minimum shall identify:

a) Item tested
b) Date of test
c) Tester or data recorder
d) Type of observation
e) Results and acceptability
f) Action taken in connection with any deviations noted
g) Person evaluating test results (usually Project Manager) – PBA may be substituted

## 12. CONTROL AND MANAGEMENT OF TEST EQUIPMENT

Tools, gages, instruments, and other measuring and test equipment used for activities affecting quality shall be controlled and shall be calibrated and adjusted at specified intervals to maintain accuracy within necessary limits. The following is the plan for regular calibration of GEOVision test equipment.

### *12.1 Calibration Plan*

**GEOVISION'S TEST EQUIPMENT CALIBRATION PLAN**

| Type | Calibration Period |
|---|---|
| Velocity and Acceleration Motion Sensors | 12 months or prior to first use after more than 12 months non-use<br><br>NOTE: Calibration is not required for geophones used only for first wave arrival measurements |
| Digital recorders, data loggers, resistivity meters, and seismographs | 12 months or prior to first use after more than 12 months non-use |
| Magnetic field and conductivity sensors including metal detectors and utility locators | N/A – used for measuring strength of field compared to background only |

The calibration periods indicated above are general; some specific pieces of equipment will require calibration more often, particularly if instability of performance is indicated.

### *12.2 Labels*

All GEOVision test equipment must have:

a) Property tag
b) Calibration label (even if "N/A"). Label must indicate the initials of the person performing the calibration, the date of calibration, and the due date for the next calibration
c) A calibration report or other log sheet in the calibration files that documents the current status of the test equipment

### *12.3 Calibration Reports*

All calibration reports must include the following:

a) Name of agency performing the test
b) ID for device being tested including manufacturer's name, model number, and serial number
c) Name of technician performing the test
d) Date of test
e) Test conditions: Temperature, humidity (if required by procedure)
f) Criteria for conformance
g) Measured data for comparison with criteria
h) Calibration equipment used including manufacturer's name, model number, NIST traceable test number
i) Recalibration due date

# 13. HANDLING, STORAGE, AND SHIPPING

GEOVision does not manufacture, receive, store, or ship products. Control of handling, storage, cleaning, packaging, shipping, and preservation of items except documents is not considered applicable to the activities of GEOVision.

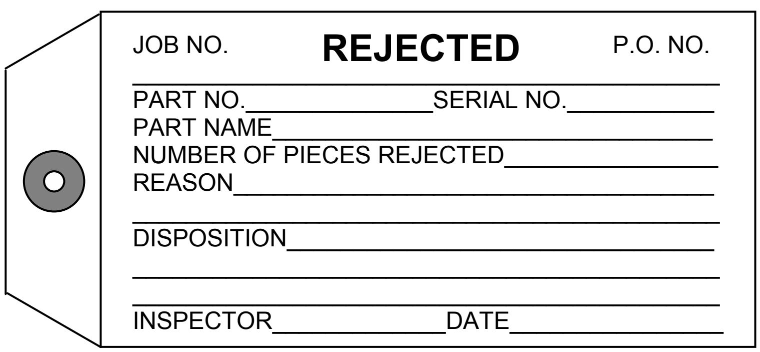
While a project is underway, original data must be stored in two places, such as on a laptop and on a thumbdrive or CDROM. Work products must be backed up regularly during the project, and at the conclusion, original data, documents and drawings are stored on the GEOVision file server “geoserv” under “Geovision/Project Files/XX/YY” (where XX is the year and YY is the job number), or , for drawings, under the CAD directory. These files must be properly backed up daily and weekly, and maintained for a minimum of three years.

# 14. INSPECTION, TEST, AND OPERATING STATUS

Except for control and management of test equipment (see Section 12), and of non-conforming items (see Section 15), control and indication of status of items is not considered applicable to the activities of GEOVision.

# 15. CONTROL OF NON-CONFORMING ITEMS

Control of non-conforming items or documents or other results is already addressed elsewhere in this document (sections 2.4, 3.3, 4.5, 10.3, and 10.5). In addition, where applicable, a non-conforming item shall be tagged with a red “REJECTED” tag affixed in a clearly visible location and with the recommended action indicated thereon. This applies particularly for equipment or software which fails to meet the requirements of any test procedure.




# 16. CORRECTIVE ACTION

## *16.1 Items or Documents*

Corrective action of conditions or non-conforming items or documents or other results is addressed elsewhere in this document (sections 2.4, 3.3, 4.5, 10.3, 10.5, and 15).

The identification and control of non-conforming items or documents may be achieved by:

a) Corrective Action Request Form (during Project QA Review, Section 2.4, or inspection, Section 10.3)
b) Memorandum of Calculation Deficiencies (Section 3.3)
c) Rejection of non-conforming purchased parts or services (Section 4.5)
d) Inspection of items, activities, or work-in-process (Section 10.3)
e) Affixing of red "REJECTED" tags on non-conforming items (Section 15)

Corrective action must be initiated within 30 days of QA Review. The Corrective Action Request Form requires that the corrective action be verified by the QA reviewer prior to billing authorization.

Significant conditions adverse to quality otherwise discovered (apart from QA Review process) shall be identified, documented, and reported to the QA Manager via the Corrective Action Request Form. Any employee of GEOVision or its subsidiaries may complete and submit a Corrective Action Request Form. Said form shall document the condition, the actions taken, and the follow-up and close out.

### *16.2 10CFR21*

From time to time GEOVision will accept projects that are nuclear safety related and fall under the scope of 10CFR21. The procedures and forms that will apply to these projects are presented in the independent procedure "10 CFR 21 PROGRAM PROCEDURE" (Reference 2).

## 17. QUALITY ASSURANCE RECORDS

Quality Assurance Records relating to any project are filed in the Project File. They shall be identifiable and retrievable by sales order number or customer name, project, and date-of-service. These include, but are not limited to:

1. Job Orders.
2. Project Design Criteria
3. Calculation Title Sheets
4. Completed Test Procedures
5. Corrective Action Request Forms
6. Billing Authorization forms.
7. Any 10 CFR 21 forms created in compliance with the "10 CFR 21 PROGRAM PROCEDURE" (Reference 2).

While a project is underway, original data must be stored in two places, such as on a laptop and on a thumbdrive or CDROM. Work products must be backed up regularly during the project, and at the conclusion, original data, documents and drawings are stored on the GEOVision file server "geoserv" under "Geovision/Project Files/XX/YY" (where XX is the year and YY is the job number), or , for drawings, under the CAD directory. These files must be properly backed up daily and weekly, and maintained for a minimum of three years.

## 18. AUDITS

This section prescribes the requirements for a comprehensive system of planned and documented audits to verify compliance with and to determine the effectiveness of this program.

### *18.1 Definitions*

| | |
|---|---|
| *Internal Audit*: | Audit of this program by GEOVision personnel. |
| *Client-Supplied Audit*: | Audit of this program by client auditors |

The adequacy and effectiveness of the Quality Assurance Program will be continually monitored through a comprehensive system of internal, supplier, and customer-provided audits. The audit system will use the Quality Assurance Program Audit to:

1. Verify that this Quality Assurance Program has been implemented as required.
2. Identify deficiencies or non-conformance in this Quality Assurance Program.
3. Verify the correction of any identified deficiencies or non-conformances.
4. Assess the adequacy and effectiveness of this Quality Assurance Program.
5. Provide written reports that will be presented to the Quality manager.

After review and action, if any, the audits and reports (if any) will be stored on the GEOVision file server "geoserv" under "Geovision/Admin/QA". These files must be properly backed up daily and weekly, and maintained for a minimum of three years.

### *18.2 Implementation*

The selection of vendors includes strong consideration of past quality performance. New vendors are subject to site inspection for an appreciation of their capabilities. Subsequent supplier surveys are scheduled at intervals consistent with the importance, complexity, and quantity of the product or services, or when otherwise deemed proper by the Quality Manager.

A triennial internal audit of the GEOVision Quality Assurance Program is performed by the Quality Manager or his/her designee.

## REFERENCES:

1. "GEOVision FY 2003 Reorganization and Management Responsibility" revised March 9, 2004.

2. GEOVision's "10 CFR 21 PROGRAM PROCEDURE" implemented November 21, 2007

# QUALITY ASSURANCE PROGRAM

## GEOVision Inc.

# EMPLOYEE SIGNATURE PAGE

I have received a copy of the GEOVision Quality Assurance Program manual.

Revision dated: ______2.0    10-15-14________________

Employee name (print): ____________________________________________________

Employee signature: _______________________________________________________

Date: ____________________________________

This signature page will be stored in each employee's personnel file.

## APPENDIX:  EXAMPLE QA DOCUMENTS

# GEOVision

# CORRECTIVE ACTION REQUEST FORM

| | |
|---|---|
| **To:**<br><br><br><br>**From:** | **Job Number:** ______________________________<br>**Copies to: Quality Manager**_________________<br>**Project Manager**_________________<br>**Other**_________________<br>**Other**_________________<br>**CAR Date:**________________________________<br>**Response Due:**____________________________ |

**Corrective Action Request:**

**Recommended Corrective Action:**

**Corrective Action:**

**Completion Date:**________________________ **Project Manager**______________________________

**Follow-up / Notes:**

**Action close-out:**

**By:**____________________________________________________________ **Date** _________________

**Quality Manager:**________________________________________________ **Date:** _________________

# Appendix C

# Field Guidance Document for Drilling of Soil Borings

**Americas**

# Underground Utilities and Subsurface Installation Clearance Process

**S3NA-417-PR1**

## 1.0 Purpose and Scope

1.1 Provides procedures designed to help prevent injuries to personnel working on the project and pedestrians, property damage, and adverse environmental impact as a result of potential hazards associated with encountering underground utilities, subsurface installations, and potential overhead hazards.

1.2 Provides the minimum requirements to be followed for underground work (e.g., excavations, drilling, boring, and probing work) to ensure that underground installations, and subsurface structures, are identified properly before work commences.

1.3 This procedure applies to all Americas-based employees and operations.

1.4 The Project Manager is responsible for meeting all the requirements in this procedure

1.5 A variance provision has been included for certain requirements of this procedure found in Sections 4.3.2, 4.7.1 and 4.9. Any variance from these procedures must be approved by the **District General Manager** or the **District SH&E Manager.**

1.6 AECOM's clients may have specific procedures which must be followed to identify and map utility and subsurface structures on their properties or facilities. Following the client's procedures over this procedure must be approved by the **District General Manager** or the **District SH&E Manager**.

## 2.0 Terms and Definitions

2.1 **Underground Utilities –** All utility systems located beneath grade level, including, but not limited to, gas, electrical, water, compressed air, sewage, signalling and communications, etc.

2.2 **Ground Disturbance (GD) –** Any indentation, interruption, intrusion, excavation, construction, or other activity in the earth's surface as a result of work that results in the penetration of the ground.

2.3 **Intrusive Activities –** Excavation of soil borings, installations of monitoring wells, installation of soil gas sampling probes, excavation of test pits/trenches or other man-made cuts, cavity, trench or depression in an earth surface formed by earth removal.

2.4 **Subsurface Installation –** Includes subterranean tunnels, underground parking garages and other structures beneath the surface.

## 3.0 References

3.1 S3NA-003-PR1 SH&E Training

3.2 S3NA-405-PR1 Drilling, Boring and Direct-Push Probing

3.3 American Public Works Association, Excavator's Damage Prevention Guide and One-Call System Directory International 1990-1991, Utility Location and Coordination Committee

3.4 Learning Management System (LMS)

## 4.0 Procedure

4.1 Roles and Responsibilities

4.1.1 **Project Manager –** Initial and authorize work to proceed using the *S3NA-417-FM2 Underground Utility and Subsurface Installation Clearance Checklist*. Authorizes (with Site Supervisor and District SH&E Manager's concurrence) if interrupted due to unexpected effect.

4.1.2 **District General Manager** and **District SH&E Manager –** Authorize any variances from this procedure. Authorization to proceed with drilling if interrupted due to unexpected effect occurs.

4.2 Flow Chart/Checklist

4.2.1 *S3NA-417-FM1 Underground Utilities and Subsurface Installation Clearance Requirements* is a flow chart of the key points to know in this procedure. Prior to any intrusive subsurface work, the *S3NA-417-FM2 Underground Utility and Subsurface Installation Clearance Checklist* must be filled out and signed by the AECOM Project Manager. If the answer to any question on the checklist is "No" or "N/A", no ground disturbance can take place without the approval of the **Project Manager**. The **Project Manager** must initial the form to authorize this approval.

4.3 Urban (or Non-Urban Areas without a one-call system)

4.3.1 Be aware that in urban areas there may be subsurface installations (e.g., underground garages) and utilities (e.g., public water, sewer, and gas pipelines) that are not covered by one-call systems. These subsurface installations and utilities require addition investigation and diligence beyond the one-call system. Additional investigation and diligence beyond the one-call system is also recommended for non-urban areas.

4.3.2 Private locates, as a minimum, and hand clearing, as appropriate, are also required in urban areas. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager.** Private locates and hand clearing is also recommended for non-urban areas.

4.3.3 The presence of subsurface installations and utilities requires special care when obstructions/ refusal and voids are encountered and when unexpected absence of soil recovery occurs during drilling operations. Other indicators of subsurface installations and utilities are the presence of warning tape, pea gravel, sand, non-indigenous material, bentonite, red concrete (indicative of electrical duct banks) and any departure from native soil or backfill.

4.4 Permits and Access Agreements

4.4.1 All appropriate permits (e.g., government, working near rail road, etc.) will be identified, obtained, and adhered to.

4.4.2 All client on-site safety procedures shall be understood and adhered to, and all client permits will be obtained.

4.4.3 All access agreements will be obtained and adhered to.

4.4.4 Be aware of the Federal/State/Provincial/Territorial regulations that govern drill rig operations and exposed moving parts.

4.5 General Health and Safety

4.5.1 Health and Safety Plan – At a minimum, a health and safety plan (HASP) that includes task hazard analyses (THAs) shall be prepared prior to any drilling, boring, and direct-push probing activities. The HASP will address any required environmental monitoring including gas monitoring, dust, noise, metals, radiation or other monitoring as may be appropriate for site conditions. All HASP requirements will be followed by the AECOM project team.

4.5.2 Training

- All staff shall be trained in identifying underground utilities and subsurface installations and the requirements. Refer to the *S3NA-003-PR1 SH&E Training* and *Learning Management System (LMS).*
- All staff shall receive client-required training.

4.6 Identification and Mapping of Utility and Subsurface Structures

4.6.1 The locations of subsurface and overhead utilities and subsurface installations will be investigated, documented, and shown on a site plan (a scaled site plan shall be used when feasible). Refer to *S3NA-406-PR1 Electrical Lines Overhead* and *S3NA-417-FM2 Underground Utilities and Subsurface Installation Clearance Checklist.*

4.6.2 Documentation of utility and subsurface installation clearance along with the scaled site plan will be on site at all times of intrusive activities.

4.6.3 Identification and mapping of Utility and Subsurface Structures is iterative with the Site Walk and should be repeated as necessary following the Site Walk as appropriate.

4.7 Site Walk

4.7.1 A site walk shall be conducted by the AECOM project team/site manager with the objectives of reviewing all planned intrusive activity locations, the locations of subsurface and overhead utilities and the potential for subsurface installations, to determine the appropriate utility clearance activities, and to observe other physical hazards. If possible, particularly at urban and industrial sites, the client/property owner or someone knowledgeable about the site and site utilities will attend the site walk. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager**.

4.7.2 The site walk is iterative with the Identification and mapping of Utility and Subsurface Structures and should be repeated as necessary following the Identification and Mapping of Utility and Subsurface Structures.

4.8 Proposed Subsurface Investigation Locations

4.8.1 All proposed subsurface locations will be reviewed in comparison to subsurface and overhead utilities and subsurface installations and adjustments made as necessary.

4.8.2 Minimum set back distances from subsurface and overhead utilities and subsurface installations will be established including 5 feet (1.5 meters) from any subsurface utility, 7 feet (2.1 meters) from the pad surrounding any underground storage tanks, and 10 feet (3 meters) from any overhead energized electrical line (or further depending on line voltage). These set back distances are a minimum; government regulations and utility requirements may dictate a greater set back distance.

4.9 Utility Clearance Investigation Location Confirmation

4.9.1 In urban areas, proposed subsurface locations will be hand cleared to 5 feet/1.5 meters (soil borings and wells) or 1 foot/0.3 meter (soil gas sampling probes) using non-mechanical methods. Hand clearance should be extended if locations of deep utilities and structures are not known. In non-urban areas, hand clearing should be conducted if possible. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager.**

4.10 Surface Markings

4.10.1 Once the underground installation has been identified, proper surface markings shall be made in accordance with the guidelines from the One-Call System (811), guidance contained in this procedure or as contract-specified.

4.10.2 Color-coded surface marks (paints or similar coatings) shall be used to indicate the type, location, and route of buried installations. Additionally, to increase visibility, color-coded vertical markers (temporary stakes or flags) shall supplement surface marks.

4.10.3 All marks and markers shall indicate the name, initials, or logo of the company that owns or operates the installation and the width of the installation if it is greater than 2 inches.

4.10.4 If the surface over the buried installation is to be removed, supplemental offset marking shall be used. Offset markings shall be on a uniform alignment and shall clearly indicate that the actual installation is a specific distance away.

4.11 Uniform Color Coding

4.11.1 The colors and corresponding installation type are as follows unless otherwise contract-specified.:

Red: Electric Power Lines, Cables, Conduit, and Lighting Cables

Yellow: Gas, Oil, Stream, Petroleum, or Gaseous Materials

Orange: Communication, Alarm or Signal Lines, Cables, or Conduit

Green: Sewers and Drain Lines

White: Proposed Ground Disturbance area

Pink: Temporary Survey Markings

Blue: Potable Water

Purple: Nonpotable Water

## 5.0 Records

5.1 None

## 6.0 Attachments

6.1 S3NA-417-WI1 One-Call System Definition and Directory

6.2 S3NA-417-FM1 Flow Chart for Underground Utilities and Subsurface Installation Clearance

6.3 S3NA-417-FM2 Underground Utility and Subsurface Installation Clearance Checklist

6.4 S3NA-417-ST Underground Utilities-Jurisdictions/Regulations

**Americas**

# One-Call System (811) Definition and Directory

**S3NA-417-WI1**

## 1.0 What Is It?

1.1 It is a Federally-mandated national “Call Before Your Dig” number, 811, to provide one telephone number for excavating contractors and the general public to call for notification of their intent to use equipment for excavating, tunneling, demolition, or any other similar work. This one-call system provides the participating members an opportunity to identify and locate their underground facilities.

As descrbied on their web site (http://www.call811.com), Common Ground Alliance (CGA) was “created specifically to work with all industry stakeholders in an effort to prevent damage to underground utility infrastructure and ensure public safety and environmental protection.” CGA also services as an organization to continuously update best practices amonth the growing underground industry. The CGA web site provides current one-call information for all states and proviences.

## 2.0 Why Is It Needed?

2.1 Damage to underground facilities increased considerably following the building boom of the 1950s, 1960s, and early 1970s when the trend was to go underground with utilities. Thousands of miles of underground facilities are vulnerable to excavating machines such as backhoes, and the resulting damage can interrupt utility service and threaten life, health, and property.

## 3.0 How to Get It

3.1 811 is the designated call before you dig phone number that directly connects you to your local one call center. Each state has different rules and regulations governing digging, some stricter than others. The CGA web site provides current contact inforatmation to find state-specific information as well as links to submit an online digging request where available

## 4.0 Disclaimer

4.1 The purpose of this directory is to illustrate the extent of one-call service available. Users must verify information is current including the extent and limit of service from local sources.

| Province/State | One-Call Agency | Number |
|---|---|---|
| Canada | www.clickbeforeyoudig.com | |
| Alberta | Alberta One Call www.albertaonecall.com | 1.800.242.3447 |
| British Columbia | BC One Call www.bconecall.bc.ca | 1.800.474.6886 |
| Manitoba | Click Before You Dig www.clikckbeforeyoudigmb.com | Various – see website |
| Ontario | Ontario One Call www.on1call.com | 1.800.400.2255 |
| Québec | Onfo Excavation www.info-ex.com | 1.800.663.9228 |
| Saskatchewan | Sask 1st Call www.sask1stcall.com | 1.866.828.4888 |
| United States | www.call811.com | 811 |
| Alabama | Alabama 811 | 1.800.292.8525 |
| Alaska | Alaska Digline, Inc. | 1.800.478.3121 |
| Arizona | Arizona 811 | 1.800.782.5348 |

| Province/State | One-Call Agency | Number |
|---|---|---|
| Arkansas | Arkansas One Call | 1.800.482.8998 |
| California | (North & Central) USA North 811 | 1.800.227.2600 |
| | (South) Dig Alert | 1.800.227.2600 |
| Colorado | Colorado 811 | 1.800.922.1987 |
| Connecticut | Call Before You Dig | 1.800.922.4455 |
| Delaware | Miss Utility of Delmarva | 1.800.282.8555 |
| District of Columbia | District One Call | 1.202.265.7177 |
| Florida | Sunshine 811 | 1.800.432.4770 |
| Georgia | Georgia 811 | 1.800.282.7411 |
| Hawaii | Hawaii One Call | 1.866.423.7287 |
| Idaho | Dig Line, Inc. | 1.800.342.1585 |
| | (Bonner/Boundry) Pass Word | 1.800.626.4950 |
| | (Kootenai County) Pass Word | 1.800.428.4950 |
| | (Shoshone-Benewah) Pass Word | 1.800.398.3285 |
| Illinois | (Chicago) Digger -Chicago Utility Alert Network | 312.744.7000 |
| | (Outside of Chicago) JULIE | 1.800.892.0123 |
| Indiana | Indiana 811 | 1.800.382.5544 |
| Iowa | Iowa One Call | 1.800.292.8989 |
| Kansas | Kansas 811 | 1.800.344.7233 |
| Kentucky | Kentucky 811 | 1.800.752.6007 |
| Louisiana | LA One Call | 1.800.272.3020 |
| Maine | Dig Safe | 1.888.344.7233 |
| Maryland | (West of Chesapeake Bay) Miss Utility of Maryland | 1.800.257.7777 |
| | (East of Chesapeake Bay) Miss Utility of Delmarva | 1.800.282.8555 |
| Massachusetts | Dig Safe System, Inc. | 1.888.344.7233 |
| Michigan | Miss Dig | 1.800.482.7171 |
| Minnesota | Gopher State One Call | 1.800.252.1166 |
| Mississippi | Mississippi 811 | 1.800.227.6477 |
| Missouri | Missouri One Call System | 1.800.344.7483 |

| Province/State | One-Call Agency | Number |
|---|---|---|
| Montana | Montana 811 | 1.800.424.5555 |
| | (Flathead and Lincoln Counties) Montana One Call Center | 1.800.551.8344 |
| Nebraska | Nebraska 811 | 1.800.331.5666 |
| Nevada | USA North 811 | 1.800.227.2600 |
| New Hampshire | Dig Safe System, Inc. | 1.888.344.7233 |
| New Jersey | New Jersey One Call | 1.800.272.1000 |
| New Mexico | New Mexico 811 | 1.800.321.2537 |
| New York | (North of 5 Boroughs) Dig Safely New York | 1.800.962.7962 |
| | (5 Boroughs and Long Island) New York 811, Inc. | 1.800.272.4480 |
| North Carolina | North Carolina 811 | 1.800.632.4949 |
| North Dakota | North Dakota One Call | 1.800.795.0555 |
| Ohio | Ohio Utilities Protection Service | 1.800.362.2764 |
| Oklahoma | Call Okie | 1.800.522.6543 |
| Oregon | Oregon Utilities Notification Center | 1.800.332.2344 |
| Pennsylvania | Pennsylvania One Call System, Inc. | 1.800.242.1776 |
| Puerto Rico | Puerto Rico Public Service Commission 811 | |
| Rhode Island | Dig Safe System, Inc. | 1.888.344.7233 |
| South Carolina | South Carolina 811 | 1.888.721.7877 |
| South Dakota | South Dakota One Call | 1.800.781.7474 |
| Tennessee | Tennessee 811 | 1.800.351.1111 |
| Texas | Texas 811 | 1.800.545.6005 |
| | Lone Star 811 | 1.800.669.8344 |
| Utah | Blue Stakes of Utah | 1.800.662.4111 |
| Vermont | Dig Safe System, Inc. | 1.888.344.7233 |
| Virginia | Virginia 811 | 1.800.552.7001 |
| Washington | Utility Notification Center | 1.800.424.5555 |
| West Virginia | WV 811 | 1.800.245.4848 |
| Wisconsin | Diggers Hotline | 1.800.242.8511 |
| Wyoming | One-Call Of Wyoming | 1.800.849.2476 |

Americas

# Key Points to Know Flow Chart for Underground Utilities and Subsurface Installation Clearance

S3NA-417-FM1

## Before Any Underground Utilities and Subsurface Installation Clearance

**PERMITS AND ACCESS AGREEMENTS**

- Government and Utility/Infrastructure Permits
- Client permits and procedures
- Access Agreements

**KEY POINT:** Must obtain all permits and sign Access Agreement (if required)

↓

**GENERAL HEALTH and SAFETY**

**KEY POINT:** Must prepare Health & Safety Plan, which includes a Task Hazard Analysis.

↓

**IDENTIFICATION & MAPPING OF UTILITY and SUBSURFACE STRUCTURES**

**KEY POINT:** Must generate a comprehensive site map illustrating known locations of overhead/subsurface utilities, subsurface structures, and proposed boring locations.

**SITE WALK**

**KEY POINT:** Must perform a site walk utilizing site map and 360° view to verify known conditions and identify potential issues. Add discovered items/issues to map for use in location confirmation.

↓

**PROPOSED SUBSURFACE INVESTIGATION LOCATIONS**

**KEY POINT:** Confirm that locations meet the minimum set-back distances described in Section 4.8

↓

**UTILITY CLEARANCE INVESTIGATION LOCATION CONFIRMATION**

**KEY POINT:** Locations must be hand-cleared, as described in Section 4.9

Americas

# Underground Utility and Subsurface Installation Clearance Checklist

**S3NA-417-FM2**

| | | |
|---|---|---|
| **Location:** | | **Project #:** |
| **Contractor:** | | **Client:** |
| **Date:** | **Time:** | **Weather:** |
| **Inspector:** | | **Project Manager:** |

**Notes:**

*Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*

*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.*

| | Yes | No | N/A |
|---|---|---|---|
| **I. Permits and Access Agreements** | | | |
| 1. Have all appropriate permits been identified and obtained (e.g., drilling, encroachment, working near railroads, etc.)? | ☐ | ☐ | ☐ |
| 2. Have all client requirements, including client permits been identified and obtained? | ☐ | ☐ | ☐ |
| 3. If working off-site is(are) site access agreement(s) executed? | ☐ | ☐ | ☐ |
| **II. General Health and Safety** | | | |
| 1. Has a Health and Safety Plan been prepared for AECOM employees? | ☐ | ☐ | ☐ |
| 2. Do on-site personnel have required-level PPE? | ☐ | ☐ | ☐ |
| 3. Do on-site personnel have required-level of training? | ☐ | ☐ | ☐ |
| **III. Identification and Mapping of Utility and Subsurface Structures** | | | |
| 1. Is a Site Plan showing the proposed subsurface locations and utility locations attached to this check list? | ☐ | ☐ | ☐ |
| 2. Have utilities and subsurface installations been investigated as being present, including the following: | ☐ | ☐ | ☐ |
| a. Steam, gas and electric? | ☐ | ☐ | ☐ |
| b. Sewer and water? | ☐ | ☐ | ☐ |
| c. Subterranean tunnels? | ☐ | ☐ | ☐ |
| d. Fiber optics (Note routine utility geophysical survey will not identify fiber optic cables)? | ☐ | ☐ | ☐ |
| e. Traffic control cables? | ☐ | ☐ | ☐ |
| f. Others (identify)? | ☐ | ☐ | ☐ |
| 3. Have all Federal/State/Provincial/Territorial and other "One Call" providers marked their facilities or otherwise notified they do not have any facilities near the proposed subsurface/intrusive locations? | ☐ | ☐ | ☐ |
| 4. Has the Federal/State/Provincial/Territorial or other "One Call" provider identified what utilities and underground structures are ***not*** included in their provider system (e.g., non-utility underground structures)? | ☐ | ☐ | ☐ |

*Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*

*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.*

| | Yes | No | N/A |
|---|---|---|---|
| 5. Has a utility locating contractor performed geophysical and/or other surveys of the proposed subsurface/intrusive locations? | ☐ | ☐ | ☐ |
| 6. Were all circuits on during subsurface checks if the checks were for identifying energized lines (e.g., circuits on timers or light sensing switches)? | ☐ | ☐ | ☐ |
| 7. Are overhead utilities or obstructions present that may prevent the safe operation of drilling/excavation equipment and, if present, has the AECOM Overhead Electrical Line Acknowledgement Form been signed? | ☐ | ☐ | ☐ |
| 8. Was there visual verification that each of the proposed locations does not lie on a line connecting two similar manhole covers (e.g., sanitary sewer or storm drain)? | ☐ | ☐ | ☐ |
| 9. Was there visual verification that the ground in the vicinity of each of the proposed subsurface locations has not subsided, been excavated and patched, give the appearance it may be covering a former trench (e.g., linear cracks, sagging curbs, linear re-pavements) and do not lie on a line with any water, gas, electrical meters, utility cleanouts, or other utility boxes in the surrounding areas? | ☐ | ☐ | ☐ |
| **IV. Site Walk** | | | |
| 1. Has a site walk been performed that includes the following: | ☐ | ☐ | ☐ |
| a. Reviewing all planned intrusive locations? | ☐ | ☐ | ☐ |
| b. Adjusting locations away from subsurface utilities and installations? | ☐ | ☐ | ☐ |
| c. Determining the appropriate utility clearance activities for each location? | ☐ | ☐ | ☐ |
| d. Determining the presence and location of overhead utilities and obstructions? | ☐ | ☐ | ☐ |
| e. Walk around perimeter of the site to observe physical hazards? | ☐ | ☐ | ☐ |
| f. Walk around 50 feet (15 meters) from perimeter of the site to observe physical hazards? | ☐ | ☐ | ☐ |
| g. Walk around 50 feet (15 meters) radius from each proposed subsurface intrusion location? | ☐ | ☐ | ☐ |
| **V. Proposed Subsurface Investigation Locations*** | | | |
| 1. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utility? | ☐ | ☐ | ☐ |
| 2. Are all of the proposed subsurface locations at least 7 feet (2.1 meters) from the pad surrounding any underground storage tanks (USTs) shown on the Site Plan? | ☐ | ☐ | ☐ |
| 3. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utilities shown on the Public Right-of-Way street improvements? | ☐ | ☐ | ☐ |
| 4. Are all proposed subsurface locations requiring a drill rig for installation at least 10 feet (3 meters) from any energized overhead power line (or further based on line voltage)? | ☐ | ☐ | ☐ |
| 5. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utilities identified during any geophysical survey performed using ground-penetrating radar (GPR) in conjunction with other technology? | ☐ | ☐ | ☐ |

** These set back distances are a minimum; government regulations and utility requirements may dictate a greater set back distance.*

*Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*

*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.*

| | Yes | No | N/A |
|---|---|---|---|
| **VI. Utility Clearance Investigation Location Confirmation*** | | | |
| 1. Have subsurface locations been hand cleared as follows? Hand clearance should be extended if locations of deep utilities and structures are not known. In non-urban areas hand clearing should be conducted if possible. | ☐ | ☐ | ☐ |
| a. For soil borings/monitoring wells excavate to a minimum of 5 feet (1.5 meters) below ground surface using non-mechanical methods. | ☐ | ☐ | ☐ |
| b. For soil gas sampling excavated to 1 foot (0.3 meter) below grade or below the bottom of a concrete floor prior to the installation of soil gas sample probe points? | ☐ | ☐ | ☐ |

* *Exceptions to requirements of the utility clearance process include the following: sites where extensive utility mapping has been completed and/or where extensive activities have already been performed; locations where facility layout is well documented and understood; and sites or portions of large sites where utilities are known not to exist currently or to not have ever existed throughout the life of the facility, property or site.*

**Americas**

# Underground Utilities – Jurisdictions/Regulations

**S3NA-417-ST**

## 1.0 Regulations

1.1 Every province and territory has strict regulations governing the procedures and practices that MUST be followed. As these regulations vary slightly, before work can commence, the Project Manager MUST review these documents and identify how all of the hazards will be addressed and how the regulations will be adhered to:

1.1.1 Occupational Health and Safety Code

1.1.2 Regional or industry-specific regulations (e.g., Alberta EUB [Pipeline Act]).

## 2.0 Occupational Health and Safety Regulations

2.1 The following Occupational Health and Safety regulations apply directly to ground disturbance:

| Jurisdiction | Regulation |
|---|---|
| **United States** | |
| **OSHA** | CFR 1926.651 |
| **Canada** | |
| **Alberta** | OHS Code (2009) Sect 441 – 464, Schedule 9 |
| **British Columbia** | OHS Regulation (1997) Sect 20.78 – 20.101 |
| **Manitoba** | Workplace Health and Safety Regulation (217/2006) Sect 26.0 – 26.47 |
| **New Brunswick** | OHS Regulation (91-191) Sect 93 – 94.1, 180 – 188 |
| **Newfoundland/Labrador** | OHS Regulation (C.N.L.R. 1165/96) Sect 139 – 148 |
| **Nova Scotia** | OHS Regulation (N.S. Reg. 44/99) Sect 153, 166 – 173 |
| **NWT/NU Territories** | General Safety Regulations (R.R.N.W.T. 1990, c. S-1), Safety Act (SI-013-92) Sect 396 – 432 |
| **Ontario** | O. Reg. 213/91 Sect 6, 7, 222 – 242 |
| **Prince Edward Island** | OHS Regulations (EC180/87) Sect 12.1 – 12.15 |
| **Quebec** | Safety Code for the Construction Industry (R.R.Q. 1981, c. S-2.1, r. 6) Sect 3.15.1 – 3.15.10 |
| **Saskatchewan** | OHS Regulation (R.R.S., c. O-1, r. 1) Sect 257 – 265, Schedule Table 17 |
| **Yukon Territory** | OHS Regulations (O.I.C. 2006/178) Sect 10.62 – 10.72 |

**Americas**

# Drilling, Boring, and Direct-Push Probing

**S3NA-405-PR1**

## 1.0 Purpose and Scope

1.1 Provides procedures designed to help prevent injuries to personnel working on the project and pedestrians, property damage, and adverse environmental impact as a result of potential hazards associated with drilling, boring and direct-push probing, including encountering underground utilities, subsurface installations, and potential overhead hazards.

1.2 Provides the minimum requirements to be followed when drilling, boring, and probing work are performed.

1.3 This procedure applies to all Americas-based employees and operations.

1.4 The **Project Manager** is responsible for meeting all the requirements in this procedure.

1.5 A variance provision has been included for certain requirements of this procedure found in Sections 4.3.2, 4.8.1 and 4.10. Any variance from these procedures must be approved by the **District General Manager** or the **District SH&E Manager.**

1.6 AECOM's clients may have specific procedures which must be followed to identify and map utility and subsurface structures on their properties or facilities. Following the client's procedures over this procedure must be approved by the **District General Manager** or the **District SH&E Manager**.

## 2.0 Terms and Definitions

2.1 **Underground Utilities –** All utility systems located beneath grade level, including, but not limited to, gas, electrical, water, compressed air, sewage, signaling, and communications, etc.

2.2 **Ground Disturbance (GD) –** Any indentation, interruption, intrusion, excavation, construction, or other activity in the earth's surface as a result of work that results in the penetration of the ground.

2.3 **Intrusive Activities –** Excavation of soil borings, installations of monitoring wells, installation of soil gas sampling probes, excavation of test pits/trenches or other man-made cuts, cavity, trench, or depression in an earth surface formed by earth removal.

2.4 **Subsurface Installations –** Includes subterranean tunnels, underground parking garages, and other structures beneath the surface.

## 3.0 References

3.1 I2-141-PR1 Subs Management Procedure

3.2 S3NA-003-PR1 SH&E Training

3.3 S3NA-205-PR1 Equipment Inspections & Maintenance

3.4 S3NA-208-PR1 Personal Protection Equipment Program

3.5 S3NA-306-PR1 Highway and Road Work

3.6 S3NA-406-PR1 Electrical Lines, Overhead

3.7 S3NA-406-FM1 Overhead Electrical Lines Acknowledgement

3.8 S3NA-417-PR1 Underground Utilities and Subsurface Installation Clearance Process

3.9 S3NA-510-PR1 Hearing Conservation Program

3.10 Learning Management System (LMS)

3.11 National Groundwater Association, 2008

3.12 Environmental Remediation Drilling Safety Guideline

## 4.0 Procedure

4.1 Roles and Responsibilities

4.1.1 **Project Manager –** Initial and authorize work to proceed using the *S3NA-405-FM2 Pre-Drilling, Boring, and Direct-Push Checklist*. Authorizes (with Site Supervisor and District SH&E Manager's concurrence) if interrupted due to unexpected effect.

4.1.2 **District General Manager** and **District SH&E Manager –** Authorize any variances from this procedure. Authorization to proceed with drilling if interrupted due to unexpected debris or concrete.

4.2 Flow Chart/Checklist

4.2.1 *S3NA-405-FM1 Key Points to Know Flow Chart for Pre-Drilling, Boring, and Direct-Push Probing* is a flow chart of the key points to know of the Pre-Drilling, Boring, and Direct-push probing requirements that are addressed in this procedure. Prior to any intrusive subsurface work, the *S3NA-405-FM2 Pre-Drilling, Boring, and Direct-Push Checklist* must be filled out and signed by the **AECOM Project Manager**. If the answer to any question on the checklist is "No" or "N/A", no ground disturbance can take place without the approval of the AECOM Project Manager. The **Project Manager** must initial the checklist to authorize this approval.

4.3 Urban (or Non-Urban Areas without a one-call system)

4.3.1 Be aware that in urban (i.e., city or town) areas there may be subsurface installations (e.g., underground garages) and utilities (e.g., public water, sewer, and gas pipelines) that are not covered by one-call systems. These subsurface installations and utilities require additional investigation and diligence beyond the one-call system. Additional investigation and diligence beyond the one-call system is also recommended for non-urban areas.

4.3.2 In urban areas, private utility locating companies must be called to identify, through geophysical surveys and other means, the presence of private utilities installed by the property owner (i.e. irrigation systems) and to verify the presence of public utilities on the properties. Hand clearing is required in urban areas. Private locates are also required in urban areas. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager.** Private locates and hand clearing is also recommended for non-urban areas.

4.3.3 The presence of subsurface installations and utilities requires special care when obstructions/ refusal and voids are encountered and when unexpected absence of soil recovery occurs during drilling operations. Other indicators of subsurface installations and utilities are the presence of warning tape, pea gravel, sand, non-indigenous material, bentonite, red concrete (indicative of electrical duct banks) and any departure from native soil or backfill.

4.4 Permits and Access Agreements

4.4.1 All applicable permits (e.g., government, working near rail road, etc.) will be identified, obtained, and adhered to.

4.4.2 All applicable client on-site safety procedures shall be understood and adhered to, and all client permits will be obtained.

4.4.3 Access agreements will be obtained and adhered to as necessary.

4.4.4 Federal/State/Provincial/Territorial regulations that govern drill rig operations and exposed moving parts shall be adhered to.

4.5 Pre-Qualifying and Re-Qualifying Drilling Subcontractors

4.5.1 All drilling subcontractors will be properly pre-qualified through AECOM's Subport (refer to *I2-141-PR1 Subs Management Procedure*). The qualifications of the drilling crew performing the work will be evaluated prior to each mobilization and each day by AECOM's on-site representative to assure that their safety performance, training, qualifications, equipment, processes, and approaches reflect AECOM standards for excellence.

4.5.2 All drilling subcontractor equipment will be properly maintained and properly equipped, and the drilling subcontractor will verify their equipment is fully functional as a normal part of their daily and pre-work routine. Refer to *S3NA-205-PR1 Equipment Inspections & Maintenance* procedure.

4.6 General Health and Safety

4.6.1 Health and Safety Plan – At a minimum, a health and safety plan (HASP) that includes task hazard analyses (THAs) shall be prepared prior to any drilling, boring, and direct-push probing activities. The HASP will address any required environmental monitoring including gas monitoring, dust, noise, metals, radiation or other monitoring as may be appropriate for site conditions. All HASP requirements will be followed by the project team.

4.6.2 Training

- All on-site staff involved with drilling, boring, and direct-push probing activities shall be provided with on-site orientation of the drill rig and its operation.
- All on-site staff involved with drilling, boring, and direct-push probing shall be trained in identifying underground utilities and subsurface installations and the requirements.
- All operators and assistants shall have industry-standard safety training and be versed in the equipment to be utilized. This training may include, but is not limited to, HAZWOPER, Petroleum Safety Training (or Construction Safety Training), and H2S Alive as appropriate. All staff involved with drilling, boring and direct-push probing activities at a client site shall receive the applicable client-required training. Refer to the *S3NA-003-PR1 SH&E Training* and *Learning Management System (LMS).*

4.6.3 Personal Protective Equipment – Refer to the *S3NA-208-PR1 Personal Protection Equipment Program* for best practices. These requirements may be modified or expanded in the HASP, which will override these requirements. Clothing shall be close fitting and comfortable without loose ends, straps, draw strings, belts, or otherwise unfastened parts that might catch on some rotating or translating component of the rig.

4.6.4 Hearing Conservation – Hearing conservation program requirements may apply when working around operating equipment. Refer to *S3NA-510-PR1 Hearing Conservation Program*. Each worker shall wear noise-reducing ear protectors around operating equipment or during elevated noise levels. Distance from the elevated noise level is the primary measure of control for non-essential drilling personnel.

4.7 Identification and Mapping of Utility and Subsurface Structures

4.7.1 The locations of subsurface and overhead utilities and subsurface installations will be investigated, documented, and shown on a site plan (a scaled site plan shall be used when feasible). Refer to *S3NA-406-PR1 Electrical Lines Overhead* and *S3NA-417 PR1 Underground Utilities and Subsurface Installation Clearance Process*.

4.7.2 Documentation of utility and subsurface installation clearance process (calling one call, responses from utilities) must be at the site along with the scaled site plan will be on-site at all times of intrusive activities.

4.8 Site Walk

4.8.1 A site walk shall be conducted by the project team/site manager with the objectives of reviewing all planned intrusive activity locations, the locations of subsurface and overhead utilities and the potential for subsurface installations, to determine the appropriate utility clearance activities, and to observe other physical hazards. If possible, particularly at urban and industrial sites, the client/property owner or someone knowledgeable about the site and site utilities will attend the site walk. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager**.

4.8.2 The Site Walk is iterative with the Identification and mapping of Utility and Subsurface Structures and should be repeated as necessary following the Identification and Mapping of Utility and Subsurface Structures.

4.9 Proposed Subsurface Investigation Locations

4.9.1 All proposed subsurface locations will be reviewed in comparison to subsurface and overhead utilities and subsurface installations and adjustments made as necessary.

4.9.2 Minimum set back distances from subsurface and overhead utilities and subsurface installations will be established including 5 feet (1.5 meters) from any subsurface utility, 7 feet (2.1 meters) from the pad surrounding any underground storage tanks, and 10 feet (3 meters) from any overhead energized electrical line (or further depending on line voltage). These set back distances are a minimum; government regulations and utility requirements may dictate a greater set back distance.

4.10 Utility Clearance Investigation Location Confirmation

4.10.1 In urban areas, proposed subsurface locations will be hand cleared to 5 feet/1.5 meters (soil borings and wells) or 2 foot/0.6 meter (soil gas sampling probes) using non-mechanical methods (including soft dig (e.g., post hole digger, air knife, hand auger, etc.). Hand clearance should be extended if locations of deep utilities and structures are not known. In non-urban areas, hand clearing should be conducted if possible. Any variance from these requirements must be approved by the **District General Manager** or the **District SH&E Manager.**

4.11 Drill Rig Inspections

4.11.1 All drill rigs will be inspected prior to the initiation of drilling and daily during drilling following the *S3NA-405-FM3 Daily Drill Rig Inspection Checklist*. This inspection is the responsibility of the drilling subcontractor who will provide written documentation of the inspection prior to the start of drilling each day.

4.12 Unanticipated Concrete/Debris or Void

4.12.1 If unanticipated concrete/debris is encountered and/or if a void is encountered, drilling will be immediately discontinued and the **Project Manager** notified. Drilling may only proceed with **District General Manager** or the **District SH&E Manager** approval.

4.13 Traffic Control

4.13.1 When operating near public vehicular and pedestrian traffic, the on-site personnel shall take every precaution necessary to see that the work zone is properly established, identified, and isolated from both moving traffic and passerby pedestrians (refer to *S3NA-306-PR1 Highway and Road Work*).

4.13.2 All traffic control devices shall be installed, placed, and maintained in accordance with a Traffic Control Plan, client specifications, and/or the Manual of Uniform Traffic Control Devices and Manual of Uniform Traffic Control Devices for Canada in Canada. Traffic control devices shall consist of and not be limited to

- Directional and informational signage;
- High visibility barricades, cones, or barrels;
- Lighting; and
- Other equipment and devices as required.

4.14 Clearing Work Areas

4.14.1 In addition to any minimum requirements the drilling subcontractor may have, prior to set up, adequate site clearing and leveling shall be performed to accommodate the rig and supplies and provide a safe working area. Clearing the site includes clearing the intended drilling area of underground utilities in accordance with *S3NA-417-PR1 Underground Utilities and Subsurface Installation Clearance Process*. Drilling or probing shall not commence when tree limbs, unstable ground, or site obstructions cause unsafe tool handling conditions.

4.15 Drilling Activities

4.15.1 In addition to any minimum requirements the drilling subcontractor may have, the following safety measures shall be taken during drilling and probing operations on site:

- The operator and helper shall be present during all active rig operations.
- Site personnel shall remain within visual contact of the rig operator.
- Hard hats, approved safety boots, safety glasses, and hearing protection shall be worn in the work zone (radius around the rig equal to the height of the drill rig mast) of a rig.
- Gas monitoring shall be conducted as appropriate.
- Hands shall be kept away from moving parts including augers.
- When observing drilling, stand upwind of the drill rig to prevent potential exposure to vapors that may be emitted from the borehole.
- The emergency shut-off switch on the rig shall be identified to site personnel and tested on a daily basis by the operator.
- Unauthorized personnel shall be kept outside of the rig work zone.
- Rig crew and other field personnel shall not use a cell phone while operating the drill rig or other equipment or within the rig work zone.
- Do not drive the rig from hole to hole with the mast (derrick) in the raised position.
- Before raising the mast (derrick) look up to check for overhead obstructions. Refer to *S3NA-417-PR1 Utilities, Underground* and *S3NA-406-PR1 Electrical Lines, Overhead*.
- Before raising the mast (derrick), all rig personnel (with the exception of the operator) and visitors should be cleared from the areas immediately to the rear and the sides of the mast. All rig personnel and visitors should be informed that the mast is being raised prior to raising it.
- Before the mast (derrick) of a drill rig is raised and drilling is commenced, the drill rig shall be first leveled and stabilized with leveling jacks and/or solid cribbing. The drill rig shall be releveled if it settles after initial set up. Lower the mast (derrick) only when the leveling jacks are down, and do not raise the leveling jack pads until the mast (derrick) is lowered completely.
- The operator of a rig shall only operate a drill rig from the position of the controls. The rig shall not be in operation if the operator of the rig leave the area of the controls
- Throwing or dropping tools shall not be permitted. All tools shall be carefully passed by hand between personnel or a hoist line should be used.
- If it is necessary to operate the rig within an enclosed area, make certain that exhaust fumes are conducted out of the area. Exhaust fumes can be toxic and some cannot be detected by smell.
- Clean mud and grease from boots before mounting a rig platform and use hand holds and railings. Watch for slippery ground when dismounting from the platform.
- During freezing weather, do not touch any metal parts of the rig with exposed flesh. Freezing of moist skin to metal can occur almost instantaneously.
- All unattended bore holes shall be adequately covered or otherwise protected to prevent rig personnel, site visitors, or animals from stepping or falling into the hole. All open bore holes shall be covered, protected, or backfilled adequately and according to Federal/State/Provincial/Territorial or local regulations on completion of the drilling project.
- When using a ladder on a rig, face the ladder and grasp either the side rails or the rungs with both hands while ascending and descending. Always use adequate fall protection and a full body harness when climbing above 6 feet (2 meters) of the ground. Do not attempt to use one

or both hands to carry a tool while on a ladder. Use a hoist line and a tool "bucket" or a safety hook to raise or lower hand tools.

4.16 Use of Manual Slide Hammer

4.16.1 The following health and safety procedures should be followed when using a manual slide hammer to install shallow injection points, drive point piezometers and drill tools:

- Only use a manual slide hammer that either attaches directly to the point/piezometer being driven or that incorporates a cap on the point/piezometer/drill tool that prevents the slide hammer from slipping off the point/piezometer/drill tool.
- Always grasp the slide manual slide hammer (handles if equipped with handles) with both hands while driving the point/piezometer/drill tool.
- Never allow hands or feet to get between the manual slide hammer and the drive plate or anvil.

4.17 Use of Augers

4.17.1 The following general health and safety procedures should be followed when supervising borings with continuous flight hollow-stem augers:

- Never place hands or fingers under the bottom of an auger section when it is being hoisted over the top of the auger section in the ground or other hard surfaces such as the drill rig platform.
- Never allow feet to get under the auger section that is being hoisted.
- When augers are rotating, stay clear of the rotating auger and other rotating components of the drill rig. Never reach behind or around a rotating auger for any reason.
- Use a long-handled shovel to move auger cuttings away from a rotating auger. Never use your hands or feet to move cuttings away from a rotating auger.
- Do not attempt to remove earth from rotating augers. Augers should be cleaned only when the drill rig is in neutral and the augers are stopped from rotating.
- Loud noises may occur while driving split spoons. At minimum hearing protection shall be worn when driving split spoons.
- Keep feet clear of rope cat head rope.

4.18 Rotary, Sonic and Core Drilling

4.18.1 In addition to the health and safety procedures identified above, the following general health and safety procedures should be followed when supervising borings with rotary, sonic and core drilling:

- Drill rods should not be braked during lowering into the hole with drill rod chuck jaws. Drill rods should not be held or lowered into the hole with pipe wrenches.
- If a string of drill rods are accidentally or inadvertently released into the hole, do not attempt to grab the falling rods with your hands or a wrench.
- When drill rods are hoisted from the hole, they should be cleaned for safe handling with a rubber or other suitable rod wiper. Do not use your hands to clean drilling fluids from drill rods.
- When drill rods are rotating, stay clear of the rotating components of the drill rig. Never reach behind or around a rotating drill rod for any reason.
- Use a long-handled shovel to move cuttings away from the top of the borehole. Never use your hands or feet to move cuttings away from the borehole.
- If work shall progress over a portable drilling fluid (mud) pit, do not attempt to stand on narrow sides or cross members. The mud pit should be equipped with rough-surfaced, fitted cover panels of adequate strength to hold drill rig personnel.
- Keep away from area where drill rods are being moved or raised to the rig. Do not stand in the area where a drill rod will fall or slide if it should be dropped.

- Loud noises may occur during drilling. Hearing protection shall be worn.

4.19 Direct-push

4.19.1 The following general health and safety procedures should be followed when supervising drilling borings with direct-push drilling:

- When drill rods are hoisted from the hole, they should be cleaned for safe handling with a rubber or other suitable rod wiper. Do not use your hands to clean drilling fluids from drill rods.
- If work shall progress over a portable drilling fluid (mud) pit, do not attempt to stand on narrow sides or cross members. The mud pit should be equipped with rough-surfaced, fitted cover panels of adequate strength to hold drill rig personnel.
- Drill rods should not be lifted and leaned unsecured against the mast. Either provide some method of securing the upper ends of the drill rod sections for safe vertical storage or lay the rods down.

4.20 Site Movement of Equipment

4.20.1 The individual who transports a rig on and off a drilling site should:

- Be properly licensed and should only operate the vehicle according to Federal/State/Provincial/ Territorial, and local regulations.
- Know the traveling height (overhead clearance), width, length and weight of the rig with carrier and know highway and bridge load, width and overhead limits, making sure these limits are not exceeded with and adequate margin.
- Allow for mast overhand when cornering or approaching other vehicles or structures.
- Be aware that the canopies of service stations and motels are often too low for a drill rig mast to clear with the mast in the travel position.
- Watch for low hanging electrical lines, particularly at the entrances to drilling sites or restaurants, motels, other commercial sites.
- Never travel on a street, road, or highway with the mast (derrick) of the rig in the raised or partially raised position.
- Remove all ignition keys if rig is left unattended unless client requirements specify that the keys remain in the ignition switch at all times.

4.20.2 Loading and Unloading

- Use ramps of adequate design that are solid and substantial enough to bear the weight of the rig with carrier, including tools.
- Load and unload on level ground.
- Use the assistance of someone on the ground as a guide.
- Check the brakes on the rig carrier before approaching loading ramps.
- Distribute the weight of the rig, carrier, and tools on the trailer so that the center of weight is approximately on the centerline of the trailer and so that some of the trailer load is transferred to the height of the pulling vehicle. Refer to the trailer manufacturer's weight distribution recommendations.
- The rig and tools should be secured to the hauling vehicle with ties, chains, and/or load binders of adequate capacity.

#### 4.20.3 Off-Road Movement

The following safety suggestions relate to off-road movement:

- Before moving a drill rig, first walk the route of travel, inspecting for depressions, stumps, gullies, ruts, and similar obstacles.
- Always check the brakes of a drill rig carrier before traveling, particularly on rough, uneven, or hilly ground.
- Discharge all passengers before moving a drill rig on rough or hilly terrain.
- Use caution when traveling side-hill. Conservatively evaluate side-hill capability of drill rigs, because the arbitrary addition of drilling tools may raise the center of mass. When possible, travel directly uphill or downhill. Increase tire pressures before traveling in hilly terrain (do not exceed rated tire pressure).
- Attempt to cross obstacles such as small logs and small erosion channels or ditches squarely, not at an angle.
- Use the assistance of someone on the ground as a guide when lateral or overhead clearance is close.
- After the drill has been moved to a new drilling site, set all brakes and/or locks. Always block/ chock the wheels.

## 5.0 Records

5.1 None

## 6.0 Attachments

| | | |
|---|---|---|
| 6.1 | S3NA-405-WI1 | Core Drilling Machine Safety Card |
| 6.2 | S3NA-405-FM1 | Key Points to Know Flow Chart for Pre-Drilling, Boring, and Direct-Push Probing |
| 6.3 | S3NA-405-FM2 | Pre-Drilling, Boring, and Direct-Push Checklist |
| 6.4 | S3NA-405-FM3 | Daily Drill Rig Inspection Checklist |
| 6.5 | S3NA-405-ST | Drilling and Boring – Jurisdictions/Regulations |

**Americas**

# Core Drilling Machine Safety Card

**S3NA-405-WI1**

## 1.0 Objective / Overview

1.1 Core drilling machines are used on all types of jobs. They can be electrical or gas powered and come with a stand or can be hand held. Caution should be used when operating such a machine. It may look harmless and easy to run, but drilling machines have many hazards.

1.2 Prior to coring activities the location should be checked for buried utilities following the Pre-Drilling, Boring and Direct-Push Checklist (S3NA-405-FM2).

## 2.0 Safe Operating Guidelines

2.1 Clean the flanges before mounting the blade.

2.2 Make sure the blade is correct for the material being cut and that the arrow on the blade corresponds with the direction of rotation of the machine spindle.

2.3 Avoid tilting the blade when cutting.

2.4 Use only the machines that have an approved safety guard.

2.5 Remove the diamond blade from the machine during transit to prevent accidental damage.

2.6 Inspect the blades frequently to detect cracks or undercutting of the steel center.

2.7 Don’t let excessive heat be generated at the cutting edge of the blade.

2.8 Use adequate water supply to both sides of the blade.

2.9 Follow the manufacturers recommended pulley sizes and operating speeds for specific blade diameters.

2.10 Make sure to tighten drive belts to ensure full available power.

2.11 Don't force the blade on the blade shaft or mount blade on an undersized spindle.

## 3.0 Potential Hazards

3.1 Utilities

3.2 Electrical shock

3.3 Flying debris

3.4 Severe cuts

3.5 Hearing loss

3.6 Breathing fumes or dust

3.7 Binding/biting – torque control

## 4.0 Training Requirements

4.1 Review of Applicable SOPs (e.g., *S3NA-305-PR1 Hand and Power Tools*; *S3NA-302-PR1 Electrical, General*).

4.2 Demonstrated knowledge on the use of a coring machine.

4.3 Review and follow manufacturers’ operating guidelines.

## 5.0 Personal Protective Equipment (Level D PPE)

5.1 Leather gloves

5.2 Face shield

5.3 Steel-toed/composite-toed boots

5.4 Hearing protection

5.5 Respirator or dust mask

## 6.0 Other Safety Tips

6.1 Keep fingers and hands away from the cutting edge.

6.2 Hold handle firmly when operating.

6.3 A subsurface utility clearance should be performed prior to initiating drilling operations.

6.4 Stand firmly and apply body weight at anchored side of guarded platform.

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# Key Points to Know Flow Chart for Pre-Drilling, Boring and Direct Push-Probing Requirements

**S3NA-405-FM1**

## Before Any Drilling, Boring and Direct Push Probing Activities

**PERMITS and ACCESS AGREEMENTS**

- **Government and Utility/Infrastructure Permits**
- **Client Permits and Procedures**
- **Access Agreements**

**KEY POINT**
Must obtain all permits and sign Access Agreement (if required).

↓

**GENERAL HEALTH and SAFETY**

**KEY POINT**: Must prepare Health & Safety Plan, which includes a Task Hazard Analysis.

↓

**IDENTIFICATION and MAPPING OF UTILITY and SUBSURFACE STRUCTURES**

**KEY POINT**: Must generate a comprehensive site map illustrating known locations of overhead/subsurface utilities, subsurface structures, and proposed boring locations.

**SITE WALK**

**KEY POINT**: Must perform a site walk utilizing site map and 360 degree view to verify known conditions and identify potential issues. Add discovered items/issues to map for use in location confirmation.

↓

**PROPOSED SUBSURFACE INVESTIGATION LOCATIONS**

**KEY POINT:** Confirm that locations meet the minimum set-back distances described in Section 4.9

↓

**UTILITY CLEARANCE INVESTIGATION LOCATION CONFIRMATION**

**KEY POINT**: Locations must be hand-cleared, as described in Section 4.10

↓

**DRILL RIG INSPECTIONS**

**KEY POINT:** Drill rig inspected and documented daily by operator prior to drilling.

↓

**BEGIN DRILLING, BORING OR DIRECT PUSH PROBING**

**KEY POINT:** Complete FM2 checklist. If unanticipated concrete/debris and/or if a void is encountered, stop work and notify the Project Manager. Authorization to proceed must have the concurrence of the Project Manager and the District General Manager or District SH&E Manager.

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# Pre-Drilling, Boring and Direct-Push Checklist

S3NA-405-FM2

| | | | |
|---|---|---|---|
| **Location:** | | **Project #:** | |
| **Contractor:** | | **Client:** | |
| **Date:** | **Time:** | **Weather:** | |
| **Inspector:** | | **Project Manager:** | |

**Notes:**

| | | | | |
|---|---|---|---|---|
| *Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*<br>*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.* | | | | |
| | | **Yes** | **No** | **N/A** |
| **I.** | **Permits and Access Agreements** | | | |
| 1. | Have all appropriate permits been identified and obtained (e.g., drilling, encroachment, working near railroads, etc.)? | ☐ | ☐ | ☐ |
| 2. | Have all client requirements, including client permits been identified and obtained? | ☐ | ☐ | ☐ |
| 3. | If working off-site is(are) site access agreement(s) executed? | ☐ | ☐ | ☐ |
| **II.** | **General Health and Safety** | | | |
| 1. | Has a Health and Safety Plan been prepared for AECOM employees? | ☐ | ☐ | ☐ |
| 2. | Do on-site personnel have required-level PPE? | ☐ | ☐ | ☐ |
| 3. | Do on-site personnel have required-level of training? | ☐ | ☐ | ☐ |
| 4. | Are appropriate monitoring equipment as specified in the HASP/THAs available at each drill rig location? | ☐ | ☐ | ☐ |
| 5. | Has the field screening equipment been calibrated as required by the HASP? | ☐ | ☐ | ☐ |
| 6. | Are calibration gases available at the site? | ☐ | ☐ | ☐ |
| 7. | Does each drill rig have a fire extinguisher, absorbent materials to cleanup a spill, and a first aid kit? | ☐ | ☐ | ☐ |
| **III.** | **Identification and Mapping of Utility and Subsurface Structures** | | | |
| 1. | Is a Site Plan showing the proposed subsurface locations and utility locations attached to this check list? | ☐ | ☐ | ☐ |
| 2. | Have utilities and subsurface installations been investigated as being present, including the following: | ☐ | ☐ | ☐ |
| | a. Steam, gas and electric? | ☐ | ☐ | ☐ |
| | b. Sewer and water? | ☐ | ☐ | ☐ |
| | c. Subterranean tunnels? | ☐ | ☐ | ☐ |
| | d. Fiber optics (Note routine utility geophysical survey will not identify fiber optic cables)? | ☐ | ☐ | ☐ |
| | e. Traffic control cables? | ☐ | ☐ | ☐ |
| | f. Others (identify)? | ☐ | ☐ | ☐ |

| *Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*<br>*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.* | | | |
|---|---|---|---|
| | **Yes** | **No** | **N/A** |
| 3. Have all Federal/State/Provincial/Territorial and other "One Call" providers marked their facilities or otherwise notified they do not have any facilities near the proposed subsurface/intrusive locations? | ☐ | ☐ | ☐ |
| 4. Has the Federal/State/Provincial/Territorial or other "One Call" provider identified what utilities and underground structures are ***not*** included in their provider system (e.g., non-utility underground structures)? | ☐ | ☐ | ☐ |
| 5. As noted in the exception at the bottom of Section VI of this checklist, has a utility locating contractor performed geophysical and/or other surveys of the proposed subsurface/intrusive locations? | ☐ | ☐ | ☐ |
| 6. Were all circuits on during subsurface checks if the checks were for identifying energized lines (e.g., circuits on timers or light sensing switches)? | ☐ | ☐ | ☐ |
| 7. If overhead utilities or obstructions are present that may prevent the safe operation of drilling/excavation equipment, has the AECOM Overhead Electrical Line Acknowledgement Form been signed? | ☐ | ☐ | ☐ |
| 8. Was there visual verification that each of the proposed locations does not lie on a line connecting two similar manhole covers (e.g., sanitary sewer or storm drain)? | ☐ | ☐ | ☐ |
| 9. Was there visual verification that the ground in the vicinity of each of the proposed subsurface locations has not subsided, been excavated and patched, give the appearance it may be covering a former trench (e.g., linear cracks, sagging curbs, linear re-pavements) and do not lie on a line with any water, gas, electrical meters, utility cleanouts, or other utility boxes in the surrounding areas? | ☐ | ☐ | ☐ |
| **IV. Site Walk** | | | |
| 1. Has a site walk been performed that includes the following: | ☐ | ☐ | ☐ |
| a. Reviewing all planned intrusive locations? | ☐ | ☐ | ☐ |
| b. Adjusting locations away from subsurface utilities and installations? | ☐ | ☐ | ☐ |
| c. Determining the appropriate utility clearance activities for each location? | ☐ | ☐ | ☐ |
| d. Determining the presence and location of overhead utilities and obstructions? | ☐ | ☐ | ☐ |
| e. Walk around perimeter of the site to observe physical hazards? | ☐ | ☐ | ☐ |
| f. Walk around 50 feet (15 meters) from perimeter of the site to observe physical hazards? | ☐ | ☐ | ☐ |
| g. Walk around 50 feet (15 meters) radius from each proposed subsurface intrusion location? | ☐ | ☐ | ☐ |
| **V. Proposed Subsurface Investigation Locations*** | | | |
| 1. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utility? | ☐ | ☐ | ☐ |
| 2. Are all of the proposed subsurface locations at least 7 feet (2.1 meters) from the pad surrounding any underground storage tanks (USTs) shown on the Site Plan? | ☐ | ☐ | ☐ |
| 3. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utilities shown on the Public Right-of-Way street improvements? | ☐ | ☐ | ☐ |
| 4. Are all proposed subsurface locations requiring a drill rig for installation at least 10 feet (3 meters) from any energized overhead power line (or further based on line voltage)? | ☐ | ☐ | ☐ |

*Questions must be answered prior to any intrusive subsurface work. DO NOT DISTURB GROUND if you have answered "No" or "N/A" to any of the questions without the approval of the AECOM Project Manager.*

*Any variance from these procedures must be approved by the District General Manager or District SH&E Manager.*

| | Yes | No | N/A |
|---|---|---|---|
| 5. Are all of the proposed subsurface locations at least 5 feet (1.5 meters) from any subsurface utilities identified during any geophysical survey performed using ground-penetrating radar (GPR) in conjunction with other technology? | ☐ | ☐ | ☐ |
| ** These set back distances are a minimum; government regulations and utility requirements may dictate a greater set back distance.* | | | |
| **VI. Utility Clearance Investigation Location Confirmation*** | | | |
| 1. Have subsurface locations been hand cleared as follows? Hand clearance should be extended if locations of deep utilities and structures are not known. In non-urban areas hand clearing should be conducted if possible. | ☐ | ☐ | ☐ |
| a. For soil borings/monitoring wells excavate to a minimum of 5 feet (1.5 meters) below ground surface using non-mechanical methods. | ☐ | ☐ | ☐ |
| b. For soil gas sampling excavated to 2 foot (0.6 meter) below grade or below the bottom of a concrete floor prior to the installation of soil gas sample probe points? | ☐ | ☐ | ☐ |

* *Exceptions to requirements of the utility clearance process include the following:*

- *Sites where extensive utility mapping has been completed and/or where extensive activities have already been performed.*
- *Locations where facility layout is well documented and understood.*
- *Sites or portions of large sites where utilities are known not to exist currently or to not have ever existed throughout the life of the facility, property or site.*

| **VII. Drill Rig Inspections** | Yes | No | N/A |
|---|---|---|---|
| 1. Structural Damage, Loose Bolts | ☐ | ☐ | ☐ |
| 2. Ropes / Cables show no signs of faying, kinking, excessive ware | ☐ | ☐ | ☐ |
| 3. Loose or Missing Guards, Fluid Leaks | ☐ | ☐ | ☐ |
| 4. Damaged Hoses and/or Damaged Pressure Gauges | ☐ | ☐ | ☐ |
| 5. Tires / Tracks in good condition. Inflated | ☐ | ☐ | ☐ |
| 6. Check and test all safety devices such as: | ☐ | ☐ | ☐ |
| a. Emergency shutdown switches, at least daily | ☐ | ☐ | ☐ |
| b. All gauges and warning lights, and ensure control levers are functioning properly | ☐ | ☐ | ☐ |
| c. First aid and fire extinguishers on drill rig | ☐ | ☐ | ☐ |
| d. Back up alarm functioning properly | ☐ | ☐ | ☐ |
| 7. Suitable storage for tools, materials, and supplies | ☐ | ☐ | ☐ |
| 8. Pipes, drill rods, casing, and augers stacked on racks to prevent rolling and sliding | ☐ | ☐ | ☐ |
| 9. Platforms and other work areas free of debris materials and obstructions | ☐ | ☐ | ☐ |
| 10. Parts / platforms, derrick can move freely with no obstructions | ☐ | ☐ | ☐ |

**Comments:**

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# Daily Drill Rig Inspection Checklist

**S3NA-405-FM3**

| | | |
|---|---|---|
| **Location:** | | **Project #:** |
| **Contractor:** | | **Client:** |
| **Date:** | **Time:** | **Weather:** |
| **Contractor Signature:** | | **Project Manager:** |

***This form is to be filled out and signed by the drilling subcontractor.***

| | Yes | No |
|---|---|---|
| **I. General Safety** | | |
| Safety Officer Designated for Job: | ☐ | ☐ |
| Name: | | |
| Safety Meeting Performed (Daily) | ☐ | ☐ |
| **II. Drill Rig Inspection** | | |
| Structural Damage, Loose Bolts | ☐ | ☐ |
| Loose or Missing Guards, Fluid Leaks | ☐ | ☐ |
| Ropes / Cables show no signs of faying, kinking, excessive ware | ☐ | ☐ |
| Damaged Hoses and/or Damaged Pressure Gauges | ☐ | ☐ |
| Tires / Tracks in good condition. Inflated | ☐ | ☐ |
| Check and test all safety devices such as: | | |
| Emergency shutdown switches, at least daily | ☐ | ☐ |
| All gauges and warning lights, and ensure control levers are functioning properly | ☐ | ☐ |
| First aid and fire extinguishers on drill rig | ☐ | ☐ |
| Back up alarm functioning properly | ☐ | ☐ |
| Comments: | | |
| **III. Drilling Operations** | | |
| Mast or derrick down when moving rig | ☐ | ☐ |
| Overhead obstructions identified before mast is raised | ☐ | ☐ |
| Drill rig stabilized using leveling jacks or solid cribbing | ☐ | ☐ |
| Secure and lock derrick | ☐ | ☐ |
| Comments: | | |
| **IV. Wire Line Hoists, Wire Rope, and Hardware** | | |
| Inspection for broken wires where reduction in rope diameter, wire diameter, fatigue, corrosion, damage from gear jamming, crushing, bird caging, kinking | ☐ | ☐ |
| Inspect and lubricate parts daily | ☐ | ☐ |

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# Key Drilling and Boring – Jurisdictions/Regulations

S3NA-405-ST

| Jurisdiction | Regulation |
|---|---|
| **United States** | |
| **OSHA** | 29 CFR 1910.212 |
| **Canada** | |
| **Alberta** | OHS Code (2014) Part 37, 756 – 779 |
| **British Columbia** | OHS Regulation (WorkSafeBC – 2013) Part 8.2 – 8.10, Part 12.84 – Part 12.92 |
| **Manitoba** | Workplace Health and Safety Regulation (217/2006) Part 41.1 – 41.22 |
| **New Brunswick** | OHS Regulation (91-191) Sect 38, 237, 241, 242,243 |
| **Newfoundland/Labrador** | OHS Regulation (C.N.L.R. 1165/96) Sect 52, 61, 68, 71, 73, 151.4, 151.5, 151.6, 163, 164, 166, 167 |
| **Nova Scotia** | OHS Regulation (N.S. Reg. 44/99) Sect 9, 87, 88 |
| **NWT/NU Territories** | General Safety Regulations (R.R.N.W.T. 1990, c. S-1), Safety Act (SI-013-92) Sect 39, 97, 141, 220 |
| **Ontario** | O. Reg 245/97 – Exploration, Drilling and Production<br>Ontario Water Resources Act: O. Reg 903 – Wells |
| **Prince Edward Island** | OHS Regulations (EC180/87) Sect 30.2, 30.8, 31.1, 45.1 |
| **Quebec** | OHS Regulation (R.R.Q., c. S-2.1, r.19.01 O.C. 885-2001) Sect 340<br>Safety Code for the Construction Industry (R.R.Q. 1981, c. S-2.1, r. 6) Sect 2.10.2, 3.10.13, 3.15.9, 4.5, 8.5 |
| **Saskatchewan** | OHS Regulation (R.R.S., c. O-1, r. 1) Part 29, 410 – 439 |
| **Yukon Territory** | OHS Regulations (O.I.C. 2006/178) Part 1.08 – 1.21, Part 14.34 – 14.38, Part 17.21 – 17.61 |

# FIELD GUIDANCE DOCUMENT NO. 001
# MANAGING INVESTIGATION-DERIVED WASTE

| | |
|---|---|
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| Applicable to ......................... | Nevada Environmental Response Trust Site<br>Henderson, Nevada |
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## Table of Contents

## 1.0 INTRODUCTION

This Field Guidance Document (FGD) describes procedures for managing investigation-derived waste (IDW) at the Nevada Environmental Response Trust Site that will be conducted by or under the oversight of ENVIRON personnel. Although this FGD describes procedures for managing IDW for this project, it should be understood that there may be details of this type of work not specifically discussed in this FGD that would be followed by personnel trained in these techniques. To ensure that management of IDW is performed safely and completely, ENVIRON personnel involved in field activities should be sure that they understand the scope of work and the level of detail necessary for each field activity prior to mobilizing to perform the work.

This FGD is intended as a guidance document and does not supersede ENVIRON Health and Safety procedures or Site-Specific Health and Safety Plan (HASP) requirements. All ENVIRON employees shall follow the guidelines, rules, and procedures contained in site-specific HASPs prior to adhering to any procedures recommended in this FGD. The ENVIRON Project Manager and Task Leader must ensure that all project personnel review and sign the applicable HASP, and that the completed HASP and relevant project information is maintained in the project file. The signatures of the Project Manager and Task Leader indicate approval of the methods and precautions outlined in the HASP. The ENVIRON Project Manager and Task Leader will also be responsible for seeing that project personnel involved in field activities follow the procedures outlined in this and other applicable FGDs.

All personnel performing on-site operations with the potential for exposure to hazardous substances or health hazards are required to be 40-hour trained in accordance with Code of Federal Regulations (CFR) 1910.120 and will meet the personnel training requirements in accordance with 29 CFR 1910.120(e).

Environmental investigation activities such as drilling and sampling may generate solid, liquid, and other wastes that must be properly managed. This FGD describes the procedures to be followed for handling and managing routine IDW, including:

- Solid waste, both hazardous and non-hazardous (e.g., soil cuttings, contaminated debris or equipment)
- Liquid waste, both hazardous and non-hazardous (e.g., purge water, rinse water from decontamination)
- Personal Protective Equipment (PPE) (e.g., gloves, spent respirator cartridges, chemical-resistant coveralls)

This FGD is not applicable to the handling of flammable liquid wastes such as non-aqueous phase liquids (NAPL), which require additional protective measures. Nor is this FGD designed to address management of industrial wastes unrelated to an environmental investigation. This FGD describes the procedures for assisting clients with on-site handling and managing of IDW; however, disposal of IDW is the responsibility of the client.

The procedures presented herein are intended to be of general use and may be supplemented by a Work Plan, Sampling and Analysis Plan, Quality Assurance Project Plan, and/or a Health and Safety Plan. Some of these procedures may not be required depending on the specific scope of work being conducted. As the work progresses, and if warranted, appropriate revisions may be made by the Task Manager. Procedures in this protocol may be superseded by applicable regulatory requirements.

## 2.0 EQUIPMENT/MATERIALS

Equipment and materials needed to conform to this FGD include:

- Health and Safety Plan (HASP)
- Site information (maps, contact numbers, previous field logs, etc.)
- Containers for waste (e.g., 55-gallon open and closed top drums, or covered roll-off bins) and material to cover waste to protect from weather
- Fire extinguisher and spill containment equipment
- Equipment for transferring solid wastes (e.g., shovels, buckets, front-end loaders, etc.)
- Equipment for transferring liquid wastes (e.g., pumps, portable tanks, etc.)
- Secondary containment pallet for drums containing liquids
- Equipment for moving containers (e.g., drum dolly, truck with lift gate, etc.)
- Air monitoring equipment (i.e., air monitoring pumps, Photoionization Detector (PID), Flame Ionization Detector (FID), other as required by the HASP)
- Water quality meters for measuring temperature, pH, and specific electrical conductance
- Sampling equipment (trowels, telescoping sampling arm, dipper or coliwasa, sample pump and tubing, etc.)
- Certified-clean sample containers and preservation supplies, sample labels, ZiplocTM bags
- Cooler with ice
- Decontamination supplies (e.g., phosphate-free detergent, alconox, distilled water)
- Tool kit with appropriate tools (socket wrench set, pry bar, drum wrench)
- Hazardous/non-hazardous waste drum labels
- Permanent marking pens
- Plastic garbage bags, ZiplockTM storage bags, roll of plastic sheeting
- PPE (Long-sleeved shirt and pants, steel-toed boots, hardhat, nitrile gloves, safety glasses with side sheets, etc.)

- Field Forms (If the project requires it, a project-specific Field Logbook may substitute for the following)
  - *Field Investigation Daily Log*

## 3.0 PROCEDURES

Several types of waste are generated during site investigations that may require special handling methods. These include solid, liquid, and used PPE. The storage and handling of these materials is discussed below.

### 3.1 Solid Waste

Soil cuttings and drilling mud generated during investigation activities shall be kept on-site in containers. Covers should be included on the containers and must be secured at all times and only open during filling activities. The containers shall be labeled in accordance with this FGD. An inventory containing the source, volume, and description of material put in the containers shall be logged on prescribed forms and kept in the project file.

### 3.2 Liquid Waste

Groundwater generated during monitoring well development, purging, and sampling can be collected in truck-mounted containers and/or other transportable containers (i.e., 55-gallon drums). Only closed-top drums will be used for storing liquid wastes; open-top drums are generally not appropriate containers for liquids. Bungs on drums must be secured at all times and only open during filling or pumping activities. The containers shall be labeled in accordance with this FGD. Waste that is generated during equipment decontamination shall be collected in a separate container. All waste containers shall be properly accounted for through an inventory process.

### 3.3 Personal Protective Equipment (PPE)

PPE that is generated throughout investigation activities shall be placed in plastic garbage bags and stored in secure containers. The containers shall be properly sealed and labeled according to this FGD. If the solid or liquid waste is characterized as hazardous waste, then the corresponding PPE should also be disposed as hazardous waste. If not, all PPE should be disposed as non-hazardous waste at an appropriate facility. Trash that is generated as part of field activities may be disposed of in regular collection facilities as long as the trash was not exposed to hazardous media.

### 3.4 Waste Container Labeling

For situations where the waste characteristics are known, the waste containers should be packaged and labeled in accordance with state and federal regulations that govern the labeling of waste. General labeling requirements are discussed below.

The following information shall be placed on all non-hazardous waste labels:

- Description of waste (i.e., purge water, soil cutting);
- Contact information (i.e., contact name and telephone number); and
- Date when the waste was first accumulated.

The following information shall be placed on all hazardous waste labels:

- Description of waste (i.e., purge water, soil cutting);
- Generator information (i.e., name, address, contact telephone number);
- EPA identification number (supplied by on-site client representative); and
- Date when the waste was first accumulated.

When the final characterization of a waste is unknown, a notification label should be placed on the drum with the words "waste characterization pending analysis" (or similar) and the following information included on the label:

- Description of waste (i.e., purge water, soil cutting);
- Generator information (i.e., contact name and telephone number);
- Date when the waste was first accumulated.

Once the waste has been characterized, the label should be changed as appropriate for a non-hazardous or hazardous waste.

Waste labels should be constructed of a weatherproof material and filled out with a permanent marker to prevent being washed off or becoming faded by sunlight. It is recommended that waste labels be placed on the side of the container, since the top is more subject to weathering.

However, when multiple containers are accumulated together, it also may be helpful to include duplicate labels on the top of the containers to facilitate organization and disposal. Each container of waste generated shall be recorded in the field notebook used by the person responsible for labeling the waste. After the waste is disposed of, either by transportation off-site or disposal on-site in an approved disposal area, an appropriate record shall be made in the same field notebook to document proper disposal of the IDW.

### **3.5** Waste Characterization

Waste characterization will be performed to determine if the IDW generated is a hazardous waste as defined by federal and state regulations. Waste characterization will be performed through the use of existing information and without additional testing if the existing information is sufficient to make a professional judgment (e.g., manifests, Material Safety Data Sheets, preliminary assessments, previous test results, knowledge of the waste generation process, direct observation of the IDW for discoloration, odor or other indicators of contamination). If existing information is not available to properly characterize the IDW, testing will be performed using USEPA-recommended methods described in SW 846: Test Methods for Evaluating Solid Waste Physical/Chemical Methods, or other methods as applicable.

Discrete samples collected during the environmental investigation may be used for waste characterization by comparing sample results to federal hazardous waste characteristic thresholds. The Toxicity Characteristic Leaching Procedure (TCLP) is the threshold based on Federal guidelines. This applies to organic as well as inorganic compounds.

Solid IDW concentrations can be compared to twenty times the established federal TCLP (20xTCLP) values. The 20xTCLP values is generally regarded as a threshold level for requiring additional leach testing to characterize the toxicity characteristics of a waste.

Acid leach testing may be performed following the federal TCLP for comparison with the TCLP value. The TCLP method uses an acetic acid buffer solution as the extraction fluid. The mixing is done for 18 hours during the TCLP test. The dilution factor is 20x for the TCLP test. If a sample has a total metal concentration less than 20x its TCLP value, it cannot fail with respect to the TCLP index even if the compound is totally soluble; hence, the comparisons to 20x TCLP values.

### 3.6 Waste Accumulation On-site

The accumulation of IDW on-site is the responsibility of the client and/or the site owner. The following procedures should be followed for accumulation of IDW.

Solid, liquid, or PPE waste generated during investigation activities that are classified as nonhazardous or “characterization pending analysis” should be disposed of as soon as possible by the client. Until disposal, such containers should be inventoried, stored as securely as possible, and inspected regularly, as a general good practice.

Solid, liquid, or PPE waste generated during investigation activities that are classified as hazardous shall not be accumulated on-site longer than 90 days. All hazardous waste containers shall be stored in a secured storage area. The following requirements for the hazardous waste storage area must be implemented:

- Proper hazardous waste signs shall be posted as required by any state or federal statutes that may govern the labeling of waste;
- Secondary containment to contain spills;
- Spill containment equipment must be available;
- Fire extinguisher; and
- Adequate aisle space for unobstructed movement of personnel.

Weekly storage area inspections shall be performed and documented to ensure compliance with these requirements. Throughout the project, an inventory shall be maintained to itemize the type and quantity of the waste generated.

### 3.7 Waste Sampling and Profiling

The waste material will be profiled and approval will be received before transportation and disposal is arranged. Final determination of the disposal site will be based on approval from the disposal facility. The facility may require profiling of the containerized IDW including collection of additional samples from the containers themselves. The following procedures will be followed for sampling IDW containers.

In general, one composite sample will be collected using a trowel or coring device from each large container or from a group of drums containing equivalent solid wastes. Small samples of soil cuttings or drill mud will be taken from several locations and depths of the handling containers and placed in sampling jars. Composite samples should not be collected in a manner to dilute high concentration wastes with low concentration wastes. Grab water samples will be collected using a dipper or composite liquid waste sampler or “coliwasa.” Sampling handling and custody procedures will be followed as described in Section 7 of this SOP. Documentation of the sampling will be performed in accordance with the procedures outlined in Section 8 herein.

If a container is known or suspected to contain a hazardous waste based on the initial characterization, the applicable procedures outlined in USEPA document, Samplers and Sampling Procedures for Hazardous Waste Streams (EPA-600/2-80-018) will be followed.

### 3.8 Waste Transport

Non-hazardous or unclassified waste that is presumed to be non-hazardous or non-designated waste may be transported on-site to a waste accumulation area using appropriate tools such as a drum dolly or a truck with a lift-gate. Containers must be properly closed during transport and care must be taken to secure the containers so they do not move in an uncontrolled manner.

Hazardous waste may be moved on-site using the same precautions as described above. However, it may not be transported using a vehicle in the public right-of-way. A state-certified hazardous waste hauler shall transport all wastes classified as hazardous. Typically, the facility receiving any waste can coordinate a hauler to transport the waste. Shipped hazardous waste shall be disposed of in accordance with all RCRA/USEPA requirements. All waste manifests or bills of lading will be signed either by the client or the client’s designee. In general, ENVIRON personnel should not sign client manifests.

### 3.9 Waste Disposal

The disposal of IDW is the responsibility of the client. This section is for assisting the client in IDW disposal. All waste generated during field activities will be stored, transported, and disposed of according to applicable state, federal, and local regulations. All wastes classified as hazardous will be disposed of by the client at a licensed treatment storage and disposal facility or managed in other approved manners.

Solid, liquid, and PPE waste will be characterized for disposal through the use of client knowledge, laboratory analytical data created from soil or groundwater samples gathered during the field activities, and/or composite samples from individual containers.

In general, waste disposal should be carefully coordinated with the facility receiving the waste. Facilities receiving waste have specific requirements that vary even for non-hazardous waste, so characterization should be conducted to support both applicable regulations and facility requirements.

### **3.10** Equipment Decontamination

The equipment used to transfer wastes, all sampling equipment, and water quality meters will be decontaminated by the following procedures:

- The sampling and waste transferring equipment (shovels, buckets, pumps) will be hand washed with phosphate-free detergent and a scrubber, then thoroughly rinsed with distilled water, or steam-cleaned.
- Water quality meter sensors will be rinsed with distilled water between sampling locations. No other decontamination procedures are necessary or recommended for these meters since they are sensitive instruments. After sampling, the meters must be cleaned and maintained per the manufacturer's requirements.
- Decontamination water will be collected and stored on-site for future disposal by the client unless other arrangements have been made.

### **3.11** Sample Handling and Custody

Samples (if required for waste characterization) will be collected, handled, and stored in such a manner that they are representative of their original condition and chemical composition. Identification of samples and maintenance of custody are important elements that must also be utilized to ensure samples characterize site conditions. All samples will be properly identified and maintained under chain-of-custody protocol to protect sample integrity. The following sections discuss the sample handling and custody requirements.

#### *3.11.1 Sample Identification*

To maintain consistency, a sample identification convention including unique identifiers for all groundwater and QC samples must be developed and followed throughout the project. The sample identifiers will be entered onto the sample labels, field forms, chain-of-custody forms, and other records documenting sampling activities.

### *3.11.2 Sample Labels*

A sample label will be affixed to all sample containers sent to the analytical laboratory. Field personnel will complete an identification label for each sample with the following information written in waterproof, permanent ink:

- Client and project number
- Sample location and depth, if relevant
- Unique sample identifier
- Date and time sample collected
- Filtering performed, if any
- Preservative used, if any
- Name or initials of sampler
- Analyses or analysis code requested

The use of pre-printed sample labels is preferred in order to reduce sample misidentification problems due to transcription errors. Sample labels must be completed and affixed to the sample container in the field at the time of sample collection.

If errors are made on a sample label, corrections will be made by drawing a single line through the error and recording the correct information. Corrections will be dated and initialed.

### *3.11.3 Containers, Preservation, and Hold Time*

Each lot of preservative and sampling containers will be certified as contaminant-free by the supplier. All preserved samples will be clearly identified on the sample label and Chain-of-Custody form. If samples requiring preservation are not preserved, field records will clearly specify the reason for the discrepancy.

Chemical activity continues in the sample until it is either analyzed or preserved. Once the sample has been preserved, the sample may be held for a period of time before analysis. The time from the collection of the sample to the analysis is defined as the holding time. The holding time varies depending on the media being sampled and the analyses being performed. The collection, preservation, and analysis of samples must be conducted to avoid exceeding relevant holding times.

### *3.11.4 Sample Handling and Transport*

Proper sample handling techniques are used to ensure the integrity and security of the samples. Samples for field measured parameters will be analyzed immediately in the field and recorded in the appropriate field forms. Samples for laboratory analysis will be transferred immediately to appropriate laboratory supplied containers in accordance with the following sample handling protocols:

- Don clean gloves before touching any sample containers, and take care to avoid direct contact with the sample;
- Samples will be quickly observed for color, appearance, and composition and recorded as necessary;
- The sample container will be labeled before or immediately after sampling;
- Sample containers and liners will be capped with Teflon®-lined caps before being placed in Ziploc™-type plastic bags. The samples will be placed in an ice chest kept at 4 °C for transport to the laboratory.
- All sample lids will stay with the original containers, and will not be mixed.
- Sample bottles will be wrapped in bubble wrap as necessary to minimize the potential for breakage during shipment.
- The *Chain-of-Custody* form will be placed in a separate plastic bag and taped to the cooler lid or placed inside the cooler. A custody seal will be affixed to the cooler if the samples are to be shipped by commercial carrier. For shipped samples, U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent Chain-of-Custody document.

### *3.11.5 Sample Chain of Custody*

Sample chain-of-custody procedures will be used to maintain and document sample integrity during collection, transportation, storage, and analysis. A sample is considered to be under the control of, and in the custody of, the responsible person if the samples are in their physical possession, locked or sealed in a tamper-proof container, or stored in a secure area.

The *Chain-of-Custody* form provides an accurate written record that traces the possession of individual samples from the time of collection in the field until they are accepted at the analytical laboratory. The Chain-of-Custody form also documents the samples collected and the analyses requested. The sampler will record the following information on the Chain-of-Custody forms:

- Client and project number
- Name or initials and signature of sampler
- Name of destination analytical laboratory
- Name and phone number of Project Leader in case of questions
- Unique sample identifier for each sample
- Data and time of collection for each sample
- Number and type of containers included for each sample
- Analysis or analyses requested for each sample

- Preservatives used, if any, for each sample
- Sample matrix for each sample
- Any filtering performed, if applicable, for each sample
- Signatures of all persons having custody of the samples
- Dates and times of transfers of custody
- Shipping company identification number, if applicable
- Any other pertinent notes, comments, or remarks

Blank spaces on the Chain-of-Custody will be crossed out and initialed by the field sampler between the last sample listed and the signatures at the bottom of the sheet.

The field sampler will sign the Chain-of-Custody and will record the time and date at the time of transfer to the laboratory or an intermediate person. A set of signatures is required for each relinquished/received transfer, including internal transfer. The original imprint of the Chain-of-Custody will accompany the sample containers and a duplicate copy will be kept in the project file.

If the samples are to be shipped to the laboratory, the original *Chain-of-Custody* relinquishing the samples will be sealed inside a plastic bag within the ice chest, and the chest will be sealed with custody tape that has been signed and dated by the last person listed on the *Chain-of-Custody*. U.S. Department of Transportation shipping requirements will be followed and the sample shipping receipt will be retained in the project files as part of the permanent *Chain-of-Custody* document. The shipping company (e.g., Federal Express, UPS) will not sign the *Chain-of-Custody* forms as a receiver; instead the laboratory will sign as a receiver when the samples are received.

## 4.0 PRECAUTIONS

Certain precautions should be taken to ensure safety during the implementation of this FGD. It is important to always remain alert and aware of your surroundings.

The activities described in this FGD require the implementation of a site-specific Health and Safety Plan to inform personnel of the hazards associated with this work and to describe the methods that will be employed to mitigate those hazards. The HASP must be prepared and approved by the Project Manager, Task Leader and the Project Health and Safety Coordinator prior to initiating field work.

## 5.0 RECORDKEEPING

Information collected during the performance of these procedures may be recorded on individual field forms. If the project requires it, a project-specific Field Logbook may replace any of the individual field forms with the exception of the Chain-of-Custody form. Following review by the Task Manager, the original field records will be kept in the project file. The following forms may be used to document the field activities:

- *Field Investigation Daily Log*
- *Equipment Calibration Log*
- *Chain-of-Custody*

The *Field Investigation Daily Log* will be completed for each day of fieldwork containing (at a minimum) the times and descriptions of the work performed, the activities of any contractors and/or visitors on-site, arrival and departure times for all involved, and any other pertinent information. For larger projects, or when otherwise deemed appropriate by the Task Manager, this information may alternatively be recorded in a field logbook. In these cases, a separate Field Logbook must be used for each project or site.

The *Equipment Calibration Log* will be used to document the calibration and status of any measuring instruments used in the field, e.g., PID/FID, water level measuring device, water quality meters, etc. The frequency and method of calibration will depend on the instrument. Any instruments used will be used in accordance with the factory-provided operating and/or service manuals.

Locations and unique identification of samples collected will be recorded on the *Field Investigation Daily Log*, a site map, and/or other appropriate forms.

Sample names, date/times, analyses to be performed and other pertinent information will be recorded on the *Chain-of-Custody* form as a means of identifying and tracking the samples.

# Appendix D

# Geophysical Survey Field Data Sheets

AECOM

## *SURFACE GEOPHYSICAL SURVEY FIELD FORM*

**DAILY REPORT**

PROJECT NUMBER: ______________ DATE: ______________ REPORT NUMBER: ______________

PROJECT & LOCATION: ______________

CLIENT: ______________ AECOM FIELD REPRESENTATIVE: ______________

SUBCONTRACTOR: ______________

SUBCONTRACTOR PERSONNEL ON SITE: ______________

BRIEF SUMMARY OF WORK PERFORMED: ______________

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FIELD REPRESENTATIVES SIGNATURE: ______________ DATE: ______________

AECOM

# *SURFACE GEOPHYSICAL SURVEY FIELD FORM*

**DAILY REPORT**

PROJECT NUMBER: ______________________ DATE: ______________ REPORT NUMBER: __________

Page #: __________

| START TIME | STOP TIME | DESCRIPTION OF ACTIVTIES: REMARKS |
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